THE GAS JOURNAL

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A Glance at the Contents—

Gas Washing.

An important contribution to the theory of gas washing is made by Mr. H. Hollings and Mr. L. Silver. [p. 307.]

Technical Assistant Required.

Applications are invited for the position of Junior Technical Assistant to the Motherwell and Wishaw Gas Department at a salary of £195 per annum. [p. 325.]

Benzole Recovery at Warrington.

The working results of the new benzole recovery plant at Warrington are given by Mr. A. Cook, Engineer and Manager to the Warrington Gas Department. [p. 306.]

Theory of Small Gas Governors.

In a paper before the London and Southern District Junior Gas Association, Mr. W. E. Benton, M.Sc., discussed the theory of gas governors as applicable to individual appliances. [p. 314.]

New Woodall-Duckham Plant at Gainsborough.

On Wednesday last Capt. H. F. C. Crookshank, M.P. for Gainsborough, officially inaugurated a new installation of Woodall-Duckham continuous vertical retorts at the works of the Gainsborough Gas Department. [p. 305.]

Technical Signpost to the "Journal."

Published to-day is our "Technical Signpost" to Vol. 204 of the "JOURNAL" covering items of outstanding technical interest during the October-December quarter of 1933. [p. 301.]

Companies' Reports.

Extracts from the Directors' Reports of the working of the following Companies during 1933 are given: Gas Light and Coke, South Metropolitan, South Suburban, Commercial, and Croydon. [p. 292.]

Fuel Research.

In a lecture before the Glasgow Sections of the Institute of Chemistry and the Society of Chemical Industry on Friday last, Dr. F. S. Sinnatt, Director of Fuel Research, summarized some of the work which is being carried out by the Fuel Research Board. [p. 299.]

Gas in the Development of the City.

Lecturing at the Birmingham University on Jan. 30, Mr. A. W. Smith, General Manager and Secretary to the Birmingham Gas Department, remarked that it was no exaggeration to say that the development of any city in these days depended to a very considerable extent upon its gas undertaking. [p. 312.]

Forthcoming Engagements

Feb. 10.—MANCHESTER AND DISTRICT JUNIOR ASSOCIATION.—Visit to Chester. Paper by Mr. H. G. Davison.
Feb. 10.—SCOTTISH JUNIOR ASSOCIATION (WESTERN DISTRICT).—Meeting. Paper by Mr. A. Bujnowski.
Feb. 12.—I.G.E.—Meetings of Finance Sub-Committee, 1.45 p.m.; Membership Sub-Committee, 2.30 p.m.; General Purposes Committee, 3.15 p.m.
Feb. 12.—GAS COMPANIES' PROTECTION ASSOCIATION.—Meeting of Committee, 5, Victoria Street, S.W. 1, 2.30 p.m.
Feb. 13.—I.G.E.—Meetings of Council, 10 a.m.; Gas Education Executive Committee, 4 p.m.
Feb. 15.—S.B.G.I.—Meeting of Council, 2.30 p.m.
Feb. 16.—SOUTHERN ASSOCIATION (WESTERN DISTRICT).—Meeting at Rougemont Hotel, Exeter, 2.30 p.m.
Feb. 16.—LONDON AND SOUTHERN JUNIOR ASSOCIATION.—Meeting. Paper by Mr. P. Lloyd.
Feb. 17.—YORKSHIRE JUNIOR ASSOCIATION.—Meeting at Shipley. Paper by Mr. L. R. Cowley.
Feb. 17.—SCOTTISH EASTERN JUNIOR ASSOCIATION.—Visit to Portobello Power Station. Paper by Mr. W. Masterton.
Feb. 21.—B.C.G.A.—Meeting of Executive Committee, 12 noon, 28, Grosvenor Gardens, S.W. 1.
Feb. 22.—B.I.F.—Visit of Joint Junior Gas Associations.
Feb. 23.—B.I.F.—Gas Salesmen's Day.
Feb. 24.—WESTERN JUNIOR ASSOCIATION.—Meeting at Bristol. Paper by Mr. C. H. Chester.
Feb. 27-March 1.—B.I.F.—Joint Gas Conference.
March 8.—MIDLAND JUNIOR ASSOCIATION.—Meeting. Paper by Mr. H. J. Reynolds.
March 10.—WESTERN JUNIOR ASSOCIATION.—Meeting at Plymouth. Paper by Mr. A. R. Langford.
March 10.—SCOTTISH JUNIOR ASSOCIATION (WESTERN DISTRICT).—Annual Business Meeting. Paper by Mr. H. S. Milne.
March 14.—I.G.E.—Meeting of Meters Committee, 2.30 p.m.
March 14.—YORKSHIRE JUNIOR ASSOCIATION.—Joint Meeting at Warrington with Manchester and District Juniors. Paper by Dr. Winter.
March 16.—LONDON AND SOUTHERN JUNIOR ASSOCIATION.—Meeting. Paper by Mr. L. T. Minchin.
March 24.—YORKSHIRE JUNIOR ASSOCIATION.—Meeting at Batley.
March 27.—SOUTHERN ASSOCIATION.—Annual General Meeting, Hotel Metropole, London, 2 p.m.
April 6.—NORTH BRITISH ASSOCIATION.—Spring Meeting at Perth.

1934 "JOURNAL" Directory.

Page 72. Misprint. WELWYN. Officers (R. Ashley, M.; R. J. Clayton, S.) refer to Wem Gas Light and Coke Company, Ltd., below. R. J. Clayton resigns on March 31, 1934.

EDITORIAL NOTES

Accounts of the Metropolitan Gas Companies

Gas Light and Coke Company

THE results disclosed by the accounts of the Gas Light and Coke Company for the year 1933 indicate that the Company has passed through satisfactorily a somewhat difficult year. The long spells of exceptionally mild weather experienced during the period have naturally affected the output of gas, but it is no mean achievement that the decrease in the sales to consumers amounts to 1·78% only, as compared with 2·54% in 1932. In the capital account, we see that a total of £613,686 was expended on new and additional buildings and distribution items, against which £235,839 has been written off for depreciation of steamships, meters, and stoves, leaving a net additional capital expenditure of £377,848. The total expended to date, less nominal additions and capital redeemed, amounts to £24,941,141, or 2s. per therm sold. No fresh capital was raised during the year, but £31,229 ordinary stock was redeemed, and the 6% Brentwood preference stock, £23,457, paid off.

Below is a comparison of the principal items of receipts and expenditure for the past two years as they appear in the revenue accounts:

Receipts.

—	1933.	1932.
	£	£
Gas (*less* public lighting expenses)	8,302,315	8,535,859
Rentals	1,587,420	1,537,202
Rents and transfer fees	49,062	47,875
	£9,938,797	£10,120,936

Expenditure.

—	1933.	1932.
	£	£
Coals, oil, &c. (*less* residuals)	1,415,703	1,438,960
Salaries and carbonizing wages	492,098	519,609
Purification	67,179	68,931
Repairs and maintenance of works and plant	1,103,711	1,526,327
Total net manufacture	3,078,691	3,553,827
Distribution	3,235,486	2,879,169
Co-partnership	107,627	110,424
Rents, rates, and taxes	730,156	642,921
Management	473,957	467,661
Miscellaneous, including annuities and contributions to superannuation funds (£212,175) and, for 1932, expenses *re* amalgamations and payments to Southend stockholders	335,115	432,253
Total expenditure (*less* residuals)	£7,961,032	£8,086,255
Balance to net revenue account	£1,977,765	£2,034,681

Examining the various items in detail, it is seen that the saving on coal alone was £160,157, the quantity carbonized being 2,810,692 tons, against 2,896,478 tons in 1932, or 85,786 tons less, while the cost per ton was 6d. lower at 20s. 2·45d. Oil accounted for £66,723 more, though there was a saving in coke used and gas purchased in bulk of £39,176, leaving coals, oil, &c., alone less by £132,610. As an offset to this, however, residuals realized less by £109,353, mainly attributable to lower receipts from coke, £131,596, and breeze, £7104. On the other hand, the revenue from tar improved by £23,296, and liquor and sulphate brought in £1546, against a loss of £4505. Net coals, oil, &c., therefore, show a saving of £23,257, the total net cost per therm sold working out at 1·36d., against 1·37d. for 1932. Large economies were effected under the heading of repairs and maintenance of works and plant, £422,616, though much of this was swallowed up in extra distribution costs, £356,317, due to heavier expenditure on repairs on mains and services and stoves. Rents, rates, and taxes also show a considerable increase, while the saving on miscellaneous items is due chiefly to the expenses of amalgamations, £107,195, charged in 1932 which do not recur. On the other side of the account, the receipts from gas are down by £223,369, but it is satisfactory to note that rentals have brought in £50,218 more, by reason mainly of increased stove rentals, though no mention is made in the report of the increased numbers at rental.

The final result shows that, after paying the interest charges, the June half-year dividend, and contributing £20,000 to redemption fund, there is a total available balance of £882,768 (against £913,768), out of which it is proposed to pay dividends at the full rates on the 4% preference stock and the 3½% maximum stock, while the rate on the ordinary stock has been maintained at £5 12s.% per annum. These payments, together with a further £20,000 to redemption fund, will absorb £696,639 and leave £186,129 (against £215,550) to be carried forward.

Following are the figures as they appear in the statement of gas made, sold, &c. A satisfactory feature is the increase of 2·4% in the public lighting sales:

—	1933.	1932.
	Therms.	Therms.
Quantity made	263,440,470	266,726,044
Quantity sold—		
Private consumers	229,273,336	233,619,980
Public lighting	4,662,607	4,553,428
Sundry processes	7,489,200	6,132,208
Correction for temperature and pressure	7,884,091	8,334,801
Total sales	249,309,234	252,640,417
Quantity used on works	2,762,475	2,813,104
Total accounted for	252,071,709	255,453,521
Not accounted for	11,368,761	11,272,523

The comparative results with which we conclude indicate the efficiency of the Company's working:

	1933.	1932.
Coal cost per ton	20s. 2·45d.	20s. 8·54d.
Therms made per ton of coal carbonized	75·65	74·87
Coke made per ton of coal carbonized (cwt.)	9·77	10·00
Tar made per ton of coal carbonized (galls.)	10·66	10·48
	s. d.	s. d.
Prices realized—		
Coke per ton	18 8·00	19 6·04
Breeze per ton	3 11·33	4 7·75
Tar per gall.	0 3·50	0 3·27
Liquor per butt	0 0·61	0 1·55*

* Loss.

South Metropolitan Gas Company

THE accounts of the South Metropolitan Gas Company show that the sales of gas to consumers have fallen by 3·7%, and the report states that this is attributable to changing conditions of living, need for economy by consumers, abnormal weather, and increasing competition. In addition, the sales of gas in bulk to the South Suburban Gas Company have declined from 4,517,150 therms to 1,942,618 therms. Despite this drop in consumption, however, a judicious administration has led to economies under practically all heads of expenditure, and the final results show little change over those for 1932. It is proposed to pay the same dividend—viz., 6% on the ordinary stock, the rate paid for the previous two years.

The capital account shows that a total of £47,790 has been expended during the year (against £103,727 in 1932), made up of buildings and plant £22,873 (against £70,666), mains £9640, meters £4763, and stoves and fires £10,514. No additional capital has been raised during the period, and the credit balance of the account now stands at £366,914. Authority is being sought at to-day's general meeting to issue further share and loan capital.

The following is a summary of the main items appearing in the revenue accounts:

Receipts.

—	1933.	1932.
	£	£
Gas (*less* public lighting expenses)	2,890,363	3,052,171
Rentals	427,531	434,953
Rents and transfer fees	6,486	6,292
	£3,324,380	£3,493,416

Expenditure.

—	1933.	1932.
	£	£
Coals (*less* residuals)	464,986	546,073
Wages (carbonizing)	192,383	213,923
Purification	54,439	60,992
Salaries of engineers, &c.	81,778	89,476
Repairs and maintenance of works and plant	509,105	519,253
Total net manufacture	1,302,691	1,429,717
Distribution	889,341	918,020
Co-partnership	67,099	67,099
Rent, rates, and taxes	134,997	137,157
Management	175,082	196,965
Miscellaneous, including superannuation fund (£85,692), Co-partnership insurance fund (£82,947), and, for 1932, expenses *re* issue of capital (£15,450)	194,534	181,849
Total expenditure (*less* residuals)	£2,763,744	£2,930,807
Balance to net revenue	560,636	562,609
Dividend and interest (net)	561,143	561,997
Leaving	£ 507*	£ 612†

* Deficit. † Surplus.

The receipts from gas and rentals have declined £169,230 by reason of the reduction in the output. Coal cost less by £91,134, owing mainly to the smaller quantity carbonized—1,115,274 tons, as against 1,239,282 tons in 1932. Receipts from residuals, however, are down by £10,047, which is largely attributable to a reduction of £35,851 from coke and breeze, though this is offset by an improved return from tar of £18,529, and a reduction in the loss of ammonia from £8111 to £836 only. Net coals are therefore better by £81,087. Repairs and maintenance of works and plant cost £10,148 less, while the distribution items show a saving of £28,679, made up principally of £16,301 on mains and services, £9405 on meters, and £15,437 for fittings, against which there is an increase of £10,878 on repairs to stoves and fires. Rents, rates, and taxes show a small saving of £2160. Management expenses were less by £21,883, which is chiefly due to a saving of £14,900 in general charges.

Following is the statement of gas made, sold, &c.:

—	1933.	1932.
	Therms.	Therms.
Quantity made	87,167,746	93 003 958
Quantity charged	82,905,033	88,384,559
Correction for temperature and pressure	2,781,543	3 081,188
Total sold	85,686,576	91,465,747
Used on works	1,417,460	1,395,529
Quantity accounted for	87,104,036	92,861,276
Quantity not accounted for	63,710 (0·07%)	142,682 (0·15%)

Comparing some of the principal working results and the costs per therm sold with those of the previous year, it is seen that the Company's high level of efficiency has been fully maintained:

	1933.		1932.
Coal cost per ton	19s. 6·13d.	..	19s. 7·43d.
Therms made per ton of coal carbonized	75·71	..	75·13
Coke made per ton of coal carbonized, cwt.	9·45	..	9·33
Tar made per ton of coal carbonized, gallons	10·50	..	10·46
	Per Therm Sold. d.		Per Therm Sold. d.
Expenditure (*less* residuals)	7·74	..	7·65
Gas, rentals, &c.	9·31	..	9·17
Balance, being profit	1·57	..	1·52
Dividend and interest	1·57	..	1·48
Surplus	..	..	0·04
Contributions to funds	..	..	0·04

Commercial Gas Company

CLIMATIC and trade conditions play a large part in the year's results of any gas undertaking, but in no case perhaps is this so marked as in that of the Commercial Gas Company; for by reason of its area of supply being completely built over, there is little opportunity for extension of premises. New business has to be won in the teeth of very keen competition, while adverse weather conditions are immediately reflected in the output of gas. Trade has undoubtedly improved in the Company's district during the past year, and this has brought a decrease in the sale of gas of 4·15% in 1932 down to a decrease of 2·39% only for the year under review.

The capital account shows that £26,274 has been expended on freehold property, and £4367 on new and additional prepayment meters and fittings, against which are credits from mains and services, meters, and stoves, totalling £9955, leaving a net addition to capital of £20,686. The total capital expended (less nominal additions) per therm sold works out at 1s. 10·82d., against 1s. 9·98d. at Dec. 31, 1932. On the other side of the account, it is noticed that a further £21,950 ordinary stock has been exchanged during the year for £21,072 5% irredeemable debenture stock, leaving an amount of about £50,000 ordinary stock still outstanding to be exchanged.

The following comparison of the receipts and expenditure for the past two years shows clearly that the reduced income from gas has been met by economies under most heads of expenditure:

Receipts.

—	1933.	1932.
	£	£
Gas	585,000	599,463
Rentals	93,473	96,253
Rents and transfer fees	931	1,515
	£679,404	£697,231

Expenditure.

—	1933.	1932.
	£	£
Coals (*less* residuals)	82,108	74,150
Wages (carbonizing)	45,084	35,767
Purification	8,672	6,175
Salaries of engineers, &c.	16,020	15,730
Repairs and maintenance of works and plant	67,655	90,701
Total net manufacture	219,539	222,523
Distribution	196,490	211,033
Co-partnership	13,313	13,477
Rent, rates, and taxes	35,114	35,290
Management	51,164	52,371
Miscellaneous, including superannuation, &c. (£20,348)	29,472	27,062
Total expenditure (*less* residuals)	£545,092	£561,756
Balance to net revenue	134,312	135,475
Dividend, interest, and stamp duty	138,852	139,280
Leaving a deficit of	£4,540	£3,805

There being no change in the price of gas, which has remained at 9d. per therm throughout the year, the reduction in the receipts is equivalent to the percentage referred to above. Coals alone have cost £12,628 less, chiefly owing to a reduction in the cost per ton carbonized (20s. 6d. per ton, against 21s. 2d. per ton), and also by reason of the slightly smaller quantity carbonized (250,008 tons, against 253,468 tons in 1932). Against this saving, however, there is a reduction in the receipts from residuals of £20,586, of which coke and breeze account for £24,161, while tar and ammonia have brought in more by £3575. Large economies have been effected on repairs to works and plant (£23,045 less), and in distribution costs (£14,543 less). On the other hand, carbonizing wages and purification costs have materially increased. The ultimate result is a small deficit on the year's working. It is proposed to pay a final dividend on the ordinary stock of $3\frac{1}{4}$%, making, with the interim dividend of $2\frac{1}{2}$% already paid, $5\frac{3}{4}$% for the year—the same as for 1932.

The following is the statement of gas made, sold, &c. The percentage of therms unaccounted for has fallen from 4·12 to 3·40:

—	1933.	1932.
	Therms.	Therms.
Quantity made	17,986,890	18,506,760
Quantity charged to consumers	16,461,155	16,816,420
Correction for temperature and pressure	392,535	450,320
Total sold	16,853,690	17,266,740
Used on works	520,965	478,115
Accounted for	17,374,655	17,744,855
Not accounted for	612,235	761,905

The prices realized for residuals, with the exception of a small drop in coke, all show an improvement:

	s.	d.		s.	d.
Coke (per ton)	21	6·17	..	21	11·81
Breeze (per ton)	4	5·03	..	3	3·41
Tar (per gall.)	0	3·74	..	0	3·21
Liquor (per butt)	0	11·35	..	0	10·45

The following costs per therm sold show that the final results compare very favourably with those of a year ago:

	1933. d.		1932. d.
Expenditure (*less* residuals)	7·76	..	7·81
Gas, rentals, &c.	9·67	..	9·69
Balance, being profit	1·91	..	1·88
Dividend and interest	1·98	..	1·93
Deficiency	0·07	..	0·05

A Gas Development Association

FREQUENTLY it has been a pleasure to acknowledge the progressive policy of the Halifax Gas Committee, and now we have to chronicle a further direction in which they are helping to give a useful lead to the Industry. The question of a Women's Gas Association has been discussed on several occasions in both the "JOURNAL" and the "GAS SALESMAN," but the scheme inaugurated at Halifax is "something different," being on lines which will prove beneficial in another, and some people believe more important, way.

That is to say, at a meeting presided over by Alderman Waddington (the Chairman of the Gas Committee), and attended by the Mayor (Councillor F. Austin Leach), and Mr. W. B. McLusky (the Gas Engineer and Manager), it was decided to form a Gas Development Association with the Mayoress as President, Mrs. J. H. Waddington as Vice-President, Mrs. McLusky as Treasurer, and a Committee. Meetings are to be held monthly at the Gas Showrooms, and the idea is that the Association shall concentrate upon the good work of improving service in the home—a matter in which women are primarily concerned. We feel sure that the Committee will succeed in their object of getting women more interested in the use of gas. Thus will the housewife be equipped in the best manner of all to make a right selection when confronted with the alternative of consuming either electricity or gas in her home—for, as was maintained at the meeting, every householder has a right of choice as to whether he or she will use gas or electricity. Mr. McLusky voiced the opinion that, though gas may seem to be an uninteresting subject at first, his hearers would be astonished to find how much more efficient their gas service would be when they studied it more.

We are hopeful, with the Mayor, that this new Association may have an educational effect, and if so this will be for the good both of the Halifax gas consumers in particular and of the Gas Industry in general.

Competitive Cooking

RECENTLY an important comparison has been made of gas and electricity for domestic cooking, the factors considered being convenience, cooking efficiency, and cost. The investigation was carried out by the staff of the Good Housekeeping Institute under the direction of Mrs. Cottington Taylor. Three pairs of gas and electric cookers were examined, which were considered suitable for families of three, five, and seven persons. Each cooker was tested on a seven-day week menu, the menus being intended to represent the kind of meals which would be prepared by a middle-class housewife catering at the rate of 10s. per head per week for food alone. The cookers chosen were those recommended and sold or hired by electricity and gas undertakings for the number of persons required, and were representative of those in use on the district. The whole test was, of course, entirely impartial.

Let us examine the findings. In the first place, a disadvantage of the electric oven is that heat is not immediately available. The elements have to be heated up, and some of the energy is stored up in the mass of the elements. If this energy is to be used, then the current must be switched off before the end of the cooking process, and this requires judgment. To quote the report, "electric cooking thus requires more systematic operation for ideal results. This use of residual heat is sometimes claimed as an advantage of electricity, it not being realized that the heat that is obtained after the current is switched off has to be stored during the heating-up process." Again, there is no visible evidence of the electric elements being on, unless some type of switch is used which incorporates a warning light, so that there is more chance of electricity being wasted than gas. If, however, gas is left on, the loss of heat per minute is much greater owing to the larger heat output (two or three times). In regard to the amount of operation of taps or switches there is not much difference—but the difference, a matter of 7%, favours gas.

"It was, however, realized that the three-position electric switch does not give as flexible an adjustment as a gas tap. Simmering is difficult on an electric cooker. . . . If it were imperative that food should be left simmering, then the vessel must be partially removed from the hotplate, with consequent waste of current and increased cost. On the other hand, when cooking thickened mixtures, the even distribution of heat on the electric hotplate is an advantage." We would point out that gas simmering plates can produce this advantage. "The use of the thermostat simplifies oven cooking with the gas cooker; less attention is required, and it is possible to leave a complete meal cooking in the oven; 50% more operations are required when a thermostat is not used." The thermostat is a great advantage of the gas cooker, and this advantage should be given all possible publicity.

Another important point in favour of gas cooking is speed of operation. "On the week's cooking, gas was 8% quicker on the average. Most of the saving in time was obtained on the meals required quickly—*i.e.*, breakfast and tea. In two out of the three comparisons breakfast was 30% faster by gas, tea nearly 40% faster. This speed of operation appeals to the housewife, and is a strong selling point for gas. On the water boiling tests, the time required with electricity was always greater than with gas—the excess varying from 11% to 200%, and averaging 63%. Then we come to quality of cooking, and the finding here is that it is "practically identical with gas and electric cookers." The "shrinkage in cooking" bogey is once again laid low. From the results of the tests in this respect "there is very little difference in shrinkage loss, but there is a slightly smaller loss with the electric cookers. It is, however, of interest to note that the amount of essence found in the dripping is greater with the electric cookers." Briefly, the electricity interests cannot claim any advantage over gas in the quality of cooking.

On a later page we give a cost comparison from the report on this cooking investigation, from which it will be seen that, with gas at 8·6d. per therm, the equivalent price for electricity is in all cases less than ½d. per unit, and averages 0·42d. for all the cases taken. How many electricity undertakings are in fact selling current at ½d. a unit for domestic cooking? They may advertise electricity at ½d. a unit, but the incidence of the standing charge has to be considered. We regard this method of selling, however, as of enormous advantage psychologically. The standing charge over—and the consumer knows what it is every quarter—current is ½d. a unit; and this price is most surely an incentive to the greater consumption of electricity. The report of the Good Housekeeping Institute proves clearly enough that on practically every count gas is better than electricity for cooking, and it is undoubtedly cheaper. The tests were, of course, carried out on new appliances; and it must be borne in mind that the efficiency of electric cookers depreciates with use. If electricity makes anything like an inroad into the Gas Industry's cooking load it will be because of superior sales policy and not because of any inherent merit of electricity.

Public Lighting by Gas

THE dangers of our thoroughfares are still gravely exercising the minds of the authorities and the community at large, and it seems at long last likely that legislative effort may be made to better matters. One plan which can be adopted, in the interests of safer street usage, without any additional legislation is the installation of the most efficient and most reliable form of illumination. The latter qualification is all important; for roads which are "patronized" by vehicles travelling at the speeds of express trains will give rise to great inconvenience and subject users to additional danger should there be any cessation of illumination during the hours of darkness. The best public lighting that a district can afford should be everywhere insisted upon. It has been urged that "the better the lighting the greater the speed of the motorist," but even if this be so, he would have greater responsibility in case of mishap originating with him. Recent statistics are said to have shown that fatal accidents have been numerous where street lighting is good, but, as this good lighting is presumably in the busiest thoroughfares, it is fair to assume that with indifferent lighting there would have been a still greater number of casualties.

Anyway, we regard the best practicable street illumination, in given circumstances, as a paramount duty falling upon public authorities, and that is why we are glad always to place upon record improvements in this respect. A fortnight ago we were able to announce that the Southwark Borough Council had concluded a ten-year agreement with the South Metropolitan Gas Company for the installation of 1000-c.p. high-pressure gas lamps in the Old Kent Road. The new lamps will be centrally suspended. The Gas Light and Coke Company now state that the whole length of the Chelsea Embankment will be lighted by the new centrally-hung type of lamp. Streets in the main shopping centre at Richmond are also being fitted with this type of lamp.

PERSONAL

Mr. WILLIAM DOIG GIBB, of East Dulwich Grove, London, a former Engineer and Manager of the Newcastle-upon-Tyne and Gateshead Gas Company and Chief Engineer of the South Metropolitan Gas Company, left £16,796, with net personalty £16,349.

* * *

The Council of the London and Southern District Junior Gas Association have elected as an Hon. Member of the Association Mr. WALTER GRAFTON, M.Inst.Gas E., for his endeavours in founding the Association 32 years ago. Mr. Grafton at the time was teacher in Gas Supply at the Regent Street Polytechnic, and was with the Gas Light and Coke Company. He afterwards went to the Glasgow Corporation Gas Department. Some time ago he left Glasgow, and is now living in retirement in Essex.

* * *

From a total of 109 applicants, Mr. E. L. WALLIS, of the Dudley, Brierley Hill, and District Gas Company, has been appointed Assistant Works Superintendent to the Wolverhampton Gas Company.

* * *

The departure of Mr. A. B. HORSFIELD from the City of Leeds Gas Department to take up an appointment as Assistant Fittings Superintendent with the Bristol Gas Company, was the occasion of a dinner and happy social function held at Sherwin's Restaurant, Leeds, on Thursday, Jan. 25, at which about 100 people assembled. Among those present were Mr. C. S. Shapley, the Engineer and General Manager at Leeds, together with Mr. T. Went, Superintendent, and Mr. E. R. B. French, Assistant Superintendent. Two presentations were made to Mr. Horsfield, one from his colleagues at Leeds being a grandmother clock, which was presented by Mr. Shapley. The other was a silver cigarette case from Mr. Horsfield's students at the Leeds Technical College, presented by Mr. Sykes. A first-class entertainment of music concluded a very enjoyable evening.

* * *

At a special meeting of the Directors of the Wem Gas Company last week a tribute was paid to the services of the Secretary, Mr. R. J. CLAYTON, who resigns his position on March 31. On that date Mr. Clayton will have completed 21 years' service as Secretary with the Company. In recognition of his services, the Directors, having expressed regret at his decision, elected him to a seat on the Board.

* * *

The wedding will take place shortly at Cheltenham of Mr. WILLIAM H. T. JOHNS (Deputy-Engineer and Manager of the Burnley Corporation Gas Department), elder son of Mr. W. H. Johns, M.Inst.Mech.E., Engineer and Manager of the Swansea Gas Light Company, and of Mrs. Johns, of Highmead, Sketty, Swansea, and Miss Gladys M. Orgee, daughter of the late Commander J. Orgee, D.S.C., R.N., and of Mrs. Orgee, of Abingdon, Cheltenham.

CORRESPONDENCE

Combustion of Coke

SIR,—To the discussion of the paper by Messrs. Blayden, Noble, and Riley reported in the issue of the "GAS JOURNAL" for Jan. 24 (p. 205), Dr. Anderson contributed some remarks concerning certain experiments on the combustion of coke which were carried out in the Laboratory of this Company some years ago.

As Dr. Anderson was not in close touch with the experimental work at that time, it is not surprising that his impressions are not strictly accurate. The facts are these. We found that the temperatures of ignition of cokes, semi-cokes, &c., were dependent, *inter alia*, on the content of volatile matter, although we were not aware that the relation was a "linear" one, whatever Dr. Anderson means by that phrase.

In another quite different series of experiments on the rate of travel of a fire zone through a bed of coke, we found that the said rate depended largely on the sizes of the particles used. Although such rate of travel must clearly be influenced by the ignition temperature of the fuel, we never attempted to correlate it with the volatile content of the latter, and if the rate is indeed "a linear function of the volatile matter," as Dr. Anderson states, that relation must have been established by further experimental work known to Dr. Anderson, but not to us.

Yours, &c.,
A. R. PEARSON.

South Metropolitan Gas Company,
Chemical Department,
709, *Old Kent Road, S.E.* 15,
Jan. 29, 1934.

THE NEWS OF THE WEEK

Water Pollution Research Board.—The Annual Report of the Board for the year ended June 30, 1933, was issued last Monday by the Department of Scientific and Industrial Research. It is obtainable from H.M. Stationery Office, Adastral House, Kingsway, W.C. 2, price 1s. net.

Cornish Gas Association.—At the Annual Meeting of the Cornish Gas Association held at Truro on Wednesday, Jan. 31, Mr. F. J. Nettle, Manager and Secretary of the St. Blazey Gas Company, was re-elected President for the ensuing year, and Mr. F. G. Kingwell, of Falmouth, was re-elected Hon. Secretary.

Fifty Employees, including Mr. C. Fairweather, Manager, and Mr. Fife, Assistant Manager, attended the annual Burns' Supper of the Kilmarnock Corporation Gas Department. During an interval Mr. Fairweather presented Mr. Robert Barr, late works foreman, with a wallet of notes to mark his retirement after 50 years' service.

The East Surrey Gas Company.—The Directors recommend dividends for the half-year ended Dec. 31, 1933, at the following rates per annum respectively: 6% on the cumulative preference; 5½% on the preference "A" stock; 4½% on the redeemable preference stock; and 6% on the "B" ordinary stock, all less income-tax.

Gas Supply in Tokio.—The "Journal" of the Fuel Society of Japan reports that the number of consumers supplied with gas by the Tokio Gas Company has advanced from 446,000 in 1927 to about 820,000 at the end of October last, part of the increase being due to the extension of the area supplied. As a result of the growing demand, the Company is reported to have decided to increase its productive capacity, the scheme comprising the erection of an entirely new gas-works in the vicinity of the Asano Dockyard.

Public Lighting in Wandsworth and Streatham.—Mr. G. H. King, a prominent member of the Streatham Ratepayers' Association, while walking home on a particularly cold night recently, owing to the inadequate lighting on Streatham Common had the misfortune to miss his way, and he fell into an icy cold pond. This was the story told at a ratepayers' meeting, when the lighting of the Common was being discussed. It was decided to approach the Wandsworth Borough Council on the subject. Last week the Borough Council passed a list of public lighting improvements in the borough, including that on Tooting Common. Alderman Hurley voiced the congratulations of the Council on the great improvement of the public lighting recently carried out.

"**Infra-Red Rays and Comfort**" will be the subject of a paper to be read by Sir Leonard Hill, F.R.S., on Wednesday, Feb. 14, before the Institution of Heating and Ventilating Engineers.

The Coke Ovens and Bye-Product Plant of the Blaenavon Company, Ltd., which have been idle since the general strike of 1926, are to be re-started at an early date, states the Cardiff Correspondent of *The Times*, and about 120 men will be taken on. Though no reference is made to the blast furnaces, there is reason to believe, according to reports in circulation, that early developments now in contemplation may lead to the blast furnaces being recommissioned. The coke oven plant of Dorman Long & Co., Ltd., at Redcar, has just been re-started after two and a half years' idleness.

Members of the City Business Club recently paid a visit to the Edinburgh Corporation Gas-Works at Granton. The party were received by Councillors Fergus Harris and Muter, respectively Chairman of the Public Utilities Committee and Convener of the Gas Sub-Committee, and Mr. James Jamieson, Engineer and Manager of the Gas Department. After being shown through the various departments, Mr. T. Graham, President of the Club, expressed the thanks of the members to those officials responsible for the visit. An interesting outline of some of the most recent developments in the service were given by Mr. Jamieson, and Councillors Fergus Harris and Muter also spoke. Councillor Muter emphasized the value of the gas services to the Edinburgh community.

Cost Comparison of Gas and Electricity for Cooking.

The staff of the Good Housekeeping Institute, under the direction of Mrs. Cottington Taylor, have carried out a comparison of gas and electricity for domestic cooking in convenience, cooking efficiency, and cost. Comment on the report of this comprehensive investigation, which was quite impartial, is made in our editorial columns to-day. Three pairs of gas and electric cookers were examined, which were considered suitable for families of 3, 5, and 7 persons, and each cooker was tested on a 7-day week menu. The menus were intended to represent the kind of meals which would be prepared by a middle-class housewife catering at the rate of 10s. per head per week for food alone.

The cookers chosen were those recommended and sold or hired by electric and gas undertakings for the number of persons required, and were as far as possible representative

of cookers to be found in domestic houses in the London area. They were:

No. of Persons.	Electric Cooker.	Gas Cooker.
3	91 J Jackson	No. 1 Bungalow
5	34 A Belling	No. 1 New World
7	732 Magnet	No. 1 G.L.C.

Two of the electric cookers are normally supplied with electric kettles, and these were used during the tests.

The comparison of costs with the two media has been expressed by giving the price per unit at which the cost of electricity equals that of gas at 8·6d. per therm. With the original combinations of cookers and utensils this equivalent price, averaged over the whole week, was 0·54d., 0·41d., and 0·50d. for the 3, 5, and 7 persons respectively. From these data and those supplied by water boiling tests figures were deduced for comparisons of:

1. Gas cooker with normal kettle—Electric cooker with normal kettle.
2. Gas cooker with turbine kettle—Electric cooker with machined case kettle.
3. Gas cooker with gas kettle—Electric cooker with electric kettle.

These figures are given in the accompanying table, and it is seen that the equivalent price is in all cases less than ½d. a unit, and averages 0·42d. for all the cases taken.

No. of Persons.	Cost of Food.	Gas Cooker *cf.* Electric Cooker.		Gas Cooker and Turbine Kettle *cf.* Electric Cooker and Machined Kettle.		Gas Cooker and Gas Kettle *cf.* Electric Cooker and Electric Kettle.	
		Cost of Gas.	Equivalent Price of Electricity.	Cost of Gas.	Equivalent Price of Electricity.	Cost of Gas.	Equivalent Price of Electricity.
3	£ s. d. 1 15 1	s. d. 0 11¾	d. 0·47	s. d. 0 11	d. 0·445	s. d. 0 10¾	d. 0·50
5	2 9 7½	1 2	0·385	1 1½	0·395	1 1½	0·46
7	3 15 1	1 8½	0·47	1 7¾	0·455	1 7½	0·48

Reconstruction of Vertical Retorts at Leicester.

The Leicester City Council at their January meeting approved the proposal of the Gas Committee to carry out reconstruction work in connection with the carbonizing plant at their Belgrave Gate Works.

Mr. James Mitchell, Engineer and Manager to the City of Leicester Gas Department, states that the scheme includes the immediate replacement of half of the original Glover-West settings by New Model retorts and the erection of new coal and coke handling plant, including screens, for the whole of the retort house. In addition a waste-heat boiler will be provided. The alteration will mean that the capacity of the settings will be doubled.

Price Reduction at Ripon.

Efficiency of Drakes Vertical Installation.

The price of gas in Ripon is to be reduced for ordinary meter consumers from 11½d. to 10½d. per therm from the end of the present quarter. Prepayment meters now set at 17 c.ft. with discount allowed on collection to 18·6 c.ft. for 1d. net.

A sliding scale of reduced charges to consumers of more than 30,000 c.ft. per quarter has been adopted whereby in successive stages consumers using more than 250,000 c.ft. per quarter can purchase gas at 5·7d. per therm.

Since the installation of the Drakes vertical retorts in August, 1933, carbonizing efficiency has been increased by 34·9% over the previous year.

Output at Penrith Reaches Record Figure.

For the first time in the history of the Penrith Gas-Works, which are controlled by the local Urban Council, the manufacture of gas has passed the ninety-million mark, the actual amount manufactured in 1933 having been 91,488,700 c.ft.

This, said one of the members at a meeting last week, was a pinnacle which the Gas Engineer (Mr. J. Corrigan), who presented a report, had long desired to reach, and it was a credit to him and the Council, as the owners of the works. This, coupled with the great success of the coke-grading plant, was something on which the Council could congratulate themselves.

In reply to a question as to whether there had been an increase in the sales of coke following the purchase of the new equipment, the Chairman of the Gas Committee, said there had been a very satisfactory increase. Before they purchased the grading and screening plant the Council had a huge stock of coke and could not dispose of it. They had now regained some old customers and secured new ones, and the time might not be far distant when they would have to consider whether or not they could take on other customers.

More Gas Used for London's Street Lighting.

Further Contracts with the Gas Light and Coke Company.

The Gas Light and Coke Company state that there was an increase of 2·4% in the gas used for street lighting last year. The amount sold in 1933 was 4,622,000 therms as against 4,555,000 therms in 1932.

The Holborn and Paddington Borough Councils have made contracts for street lighting by gas for a further 15 years. Contracts for another 10 years have been signed with the Chelsea, Richmond, Southwark, and Wanstead Councils. The whole length of the Chelsea Embankment will be lighted by the new centrally-hung type of gas lamp. Streets in the main shopping centre at Richmond are also being fitted with this new type of lamp. The Ealing, Chingford, and Hendon Councils have signed agreements with the Gas Light and Coke Company to light their streets by gas for another 7 years.

Contracts for public lighting by gas for a further 5 years have been made with the following ten Councils:

Canvey Island.
Benfleet.
Stanford-le-Hope.
Horndon-on-the-Hill.
Dunton.
Uxbridge.
Orsett.
Lee Chapel.
Great Wakering.
Little Wakering.

Gas Light and Coke Company.

The Accounts for the year ended Dec. 31, 1933, show that, after paying in respect of the June half-year dividends at the rate of £4% per annum on the 4% preference stock; £3 10s.% per annum on the 3½% maximum stock; and £5 12s.% per annum on the ordinary stock; and after contributing the sum of £20,000 to the redemption fund, and the sum due to the co-partners for the year under the provisions of the Company's Act, 1931, there is a total available balance of £882,768 0s. 1d., out of which the Directors recommend the payment of the following dividends in respect of the December half-year: On the 4% preference stock at the rate of £4% per annum; on the 3½% maximum stock at the rate of £3 10s.% per annum; and on the ordinary stock at the rate of £5 12s.% per annum; which, together with the further sum of £20,000 to be contributed to the redemption fund, will absorb £696,639 9s. 8d. and leave £186,128 10s. 5d. to be carried forward to the credit of the current year.

The Bill in Parliament, to confer further powers upon the Company; to prohibit the making by the authorities of districts in the area of supply of the Company of conditions as to the form of heat light, power, or energy, to be supplied or used in certain cases; and for other purposes, passed through all its stages and received the Royal Assent on July 28, 1933.

South Metropolitan Gas Company.

The Directors, in their report for the year ended Dec. 31, 1933, record with regret the death of Mr. Frank Day, who served the Company for forty-eight years. Mr. F. G. Brewer has been appointed to fill the vacant post of Secretary.

There have been added 2220 new consumers during the past year, but the sales of gas show a falling off, partly in bulk supply to the South Suburban Company, and partly (3·7%) in the ordinary consumption. The latter result is due to changing conditions of living, need for economy by consumers, abnormal weather, and increasing competition.

The use of high power gas for illuminating important

THE NEWS—*continued.*

thoroughfares continues to extend. During the past year over 5 miles of main roads have been so lighted, and orders are in hand for a further 4 miles. The type of lamp adopted is the standard one in general use in South London, but a more powerful pattern is in the experimental stage should higher units of illumination be required at some future time by the lighting authorities.

The extension of the business of gas supply continues to be hampered by the high price charged for coal. The output from the economically managed mines is being checked in order to keep going those which are dearly worked and inefficient. Why South London should be taxed for this purpose is not easy to understand, nor indeed why the threatened compulsory amalgamation of the two types could be expected to improve matters.

As regards the products from coal, coke and tar are selling freely, but the price obtained for ammonia has been inadequate to balance the costs of recovery. Sales of Metro-Coalite have not yet been developed to the full capacity of the plant, but the product is a satisfactory one.

A resolution will be put to the meeting to-day authorizing the issue, as and when required, of further share and loan capital in accordance with the provisions of the South Metropolitan Gas Act, 1932, and of the Gas Undertakings Act, 1929.

The Act to amend the provisions relating to the issue of ordinary and preference capital, the promotion of which was authorized by the proprietors at the extraordinary meeting in February last, became law on July 28, 1933.

Following the example of the Commercial Gas Company, a Bill is being promoted in the present session of Parliament with the object of ensuring the enjoyment of complete discretion as to their use of gas by municipal tenants. A Bill has also been deposited designed to codify practice as regards prepayment supplies and widen their basis of charge.

After providing for interest upon loan capital and the prescribed dividends on the preference stocks, the profit for the year enables a dividend to be paid on the ordinary stock at the rate of 6% per annum, less the interim dividend of 2½%.

Commercial Gas Company.

The Report of the Directors of the Commercial Gas Company for the year ended Dec. 31 last, to be presented at the general meeting on Feb. 8, states that the revenue account shows a profit for the year of £134,312 5s. 6d., which, together with the balance of £36,388 19s. 4d. brought forward from the previous year, makes a total of £170,701 4s. 10d. After providing for the payment of the interim dividend of £2 10s.%, less income-tax, paid on the ordinary stock in August last, for debenture and other interest and for Stamp Duty, there remains a balance of £89,536 10s. 5d., out of which the Directors recommend the payment of a final dividend of £3 5s.%, less income-tax, making a total for the year of £5 15s.%.

A further amount of £21,950 ordinary stock has been exchanged for £21,072 5% debenture stock (irredeemable) in the proportion of £100 ordinary stock for £96 debenture stock, and the capital account has been amended accordingly.

A Bill "To prohibit the making by housing authorities of conditions as to the form of light, heat, power, or energy to be supplied or used in certain cases in the limits of supply of the Commercial Gas Company and for other purposes" received the Royal Assent in July last.

South Suburban Gas Company.

During 1933 the consumers increased in number by 12,356, in addition to 10,920 taken over from the Sevenoaks and Tonbridge areas. The Company now supplies gas to 165,348 customers.

The sales of gas have risen 2¼%, mainly during the last three months. The demand for fittings and appliances continues, and there has been a considerable increment in the quantity of cookers and fires sold or hired.

Gas used for public lighting is more by 7¼%, 355 additional lamps having been erected for various local authorities, an interesting instance being one where the insufficiency of the electric units was corrected by placing modern gas lamps between each. On the other hand, the Lewisham Borough Council rejected the Company's proposals for re-lighting with gas their principal thoroughfares in the Company's district. The fact that no specification was issued by the Council setting out what was required made easy the acceptance of an alternative proposal against the expressed wishes of many residents.

The Bill promoted by the Company in the last Session of Parliament to authorize *inter alia* differential prices for gas in certain parts of the Company's limits of supply did not receive the approval of the Select Committee of the House of Lords and was ultimately withdrawn.

Payment is recommended of a dividend for the second half of the year of 3% on the ordinary stock, less income-tax, making the dividend for the year 6%, leaving the sum of £2121 9s. 3d. to be carried forward to the next account.

Croydon Gas Company.

The gas sold during 1933 shows a small decrease of 0·43% as compared with the year 1932. The number of consumers has increased by 4077. A new showroom has been recently opened in the Addiscombe district and has already proved to be beneficial to consumers in that area.

£50,000 maximum dividend stock was issued to consumers and employees in March at £102%, realizing £51,000.

The accounts show that after deducting dividends for the half-year ended June 30, 1933 (at the rate per annum of 7½% on the redeemable preference stock, 5% on the maximum dividend stock, and 7% on the sliding-scale stock), providing for all fixed charges, transferring £1009 9s. to reserve fund and appropriating £10,000 to the pension fund and £5000 to the renewal fund there remains for division, including the sum of £46,537 10s. brought forward from 1932, a balance of £93,564 14s. 4d., and the Directors recommend that dividends be declared for the half-year to Dec. 31, 1933, at the under-mentioned rates per annum, less income-tax: Redeemable preference stock, 7½%; maximum dividend stock, 5%; sliding-scale stock, 7%. This will absorb the sum of £47,004 7s., leaving a balance of £46,560 7s. 4d. to be carried to the next account.

Mr. Hore-Belisha Visits Wilsons & Mathiesons' Armley Works.

On Saturday, Jan. 20, Mr. Leslie Hore-Belisha, M.P., Financial Secretary to the Treasury, presided at the Annual Dinner of the Leeds Chamber of Commerce.

Following on the expression of a wish to see something of the City's Commercial activities, he visited Messrs. Wilsons and Mathiesons' Works at Armley. With him was Mr. Charles Granville Gibson, M.P.

Underground Gasification of Coal.

A step has been taken towards the underground gasification of coal, according to a report which appeared in the Soviet Press from Shakhti, in the Donetz Basin, where experiments, we are informed, have been going on for some time. The successful test is described in a statement signed by Mr. A. Kuznetsov, Head of the experimental mine "Podzemgas," and Prof. V. Federovsky, a heating expert.

The underground gasification of coal was an idea broached by the famous Russian chemist, Mendeleev.

Gas Industry not Moribund.

Mr. Robert Watson Addresses Doncaster Rotarians.

Addressing members of the Doncaster Rotary Club recently, Mr. Robert Watson, Engineer and General Manager of the Corporation Gas Department, said that though gas was very little seen in New York, it was used there to a greater extent than in any other city in the world. In Great Britain, too, gas was being used more and more in places not seen by the man in the street. The impression of decline was accentuated by the establishment of the electric grid which was provided with facilities and financial aid by the Government, a thing the Gas Industry had never had or asked for. Competition between electricity and gas was severe, but the facts were against any suggestion of decline of the Gas Industry.

Many people wishing to be thought electrically minded were still good customers for gas. Gas stock was favourably regarded by Exchange market, and the Industry was considerable, employing 113,000 men, using 18 millions of

tons of coal a year, and having over 10 millions of consumers.

Mr. Watson exhibited a diagram showing the increase in output of gas in Doncaster, as illustrative not merely of Doncaster, but other towns in the country, and generally of the national gas sales. This showed the output at the Doncaster works in 1890 was 100,000,000 c.ft., made up almost entirely of the lighting load, and in 1933, 500,000,000 c.ft., showing the lighting load as about 25% of the whole, and the balance as being new fields in cooking, heating hot water, and the commercial use of gas which the gas industry had found and in which there were still considerable opportunities for expansion.

There were 7 millions of gas cookers and almost as many gas fires in the country, and to the extent to which raw coal had been displaced had the smoke nuisance been reduced, with the consequent results of more available sunshine, reduced soap bills and better health.

Cathedral of Silver Grace.

The grimy and historic old stones of the Sheffield Cathedral acquired an unwonted beauty recently. Instead of appearing as a dark and indistinct building, the Cathedral was seen in new splendour—as a graceful silver church. It was thrown into sharp relief against the dark sky by floodlighting installed by the Sheffield Gas Company

The floodlighting installation consists of 44 gas floodlight lamps of the Foster & Pullen (Bradford) type, each capable of producing 500 to 2000 c.p., and these are placed approximately 6 to 8 ft. apart and 36 ft. from the building line. Special gas units are also placed on the tower and centre minaret, with the lights focussed in such a way as to show the whole of the steeple. Referring to this a local paper stated: "The arrangement of the floodlighting apparatus is so effective that all who admire the church by night will congratulate Mr. Ralph Halkett, General Manager and Secretary of the Sheffield Gas Company, and the staff responsible for the innovation."

Application of Machinery to the Office.

Up-to-Date Methods at Belfast.

Speaking before the Incorporated Accountants of Belfast and district on "The Application of Machinery to Office Work," Mr. W. J. M'Millan, Cashier of the Belfast Corporation Gas Department, said machines had come to stay and the next decade would see a complete changeover from the old pen and ink methods.

He did not discuss the problem raised by the introduction of machinery in relation to unemployment, but said that the rationalization of the Gas Industry had produced an expansion of business resulting in the employment of more persons than ever. In Belfast not a single person had lost his job as the result of the introduction of office machinery. He paid a tribute to the Gas Committee and the Engineer and Manager, Mr. J. D. Smith, who had been among the first to appreciate the possibilities of the new methods, resulting in large savings to the Corporation.

Machines by themselves, he said, were not enough. Operators must be efficient mentally and properly trained, but, above all, the whole office system must be properly organized and continuously supervised. No matter how many machines were used in the future, good and legible penmanship would always be an asset to its possessor.

Wallasey Adopts Gas for Road Vehicles.

Compressing Plant to be Installed.

The Wallasey Corporation intend to supply compressed coal gas for the propulsion of road vehicles. The Gas Committee will set up plant and storage station at the Gorsey Lane entrance of the Gas-Works.

The scheme, which was approved by the Council at their last meeting, also includes for the necessary steel traction cylinders, fittings, and connections for the conversion of the five motor wagons owned by the Gas Department now running on petrol.

The plant will be so designed and arranged with a view to duplication and extension of capacity both of compressing machinery and storage cylinders. The Wallasey installation will be the first of its kind on Merseyside.

Gas, under a pressure of 3000 lbs. per sq. in., will be contained in steel cylinders weighing 112 lbs. each and suitable for attachment to motor vehicles. One cylinder will last for about 20 miles' travel of a loaded lorry or 'bus. The usual equipment will be four cylinders to last for 70 to 80 miles before recharging.

Neath Gas Department Dinner.

High tribute to the efficiency of the Neath Corporation Gas Department and its enterprising Manager, Mr. W. Clark Jackson, was paid by the Chief Constable of Neath at a dinner of the staff and employees, when twelve employees were presented with certificates for long and meritorious service. The certificates were presented by Mr. George Gethin, Chairman of the Gas Committee.

Mr. P. D. Keep, the Chief Constable, said there was no danger of the town being let down by the Gas Department. Its motto was "Service," and it lived up to this motto. The Department was one of which Neath could be justly proud.

Responding to the toast, Mr. Clark Jackson compared statistics connected with the gas-works in 1877 with those of the present day, to indicate the progress made. He was proud of his staff, who, without exception, did everything they could for the good of the Department.

Fuel Research.

In a lecture before the Glasgow Sections of the Institute of Chemistry and the Society of Chemical Industry on Friday last, Dr. F. S. Sinnatt, Director of Fuel Research, summarized some of the work which is being carried out by the Fuel Research Board.

The work of the Coal Survey, said Dr. Sinnatt, is of great importance to the coal industry and indirectly to the Gas Industry. British coals range in rank from lignite to anthracite, and each coalfield therefore requires a special survey staff. Up to the present some seventy seams have been investigated in the country, either partially or completely, and each seam exhibits characteristic variations in properties from locality to locality. There is a tendency among those not alive to the magnitude of the coal interests to dismiss such variations in the properties of the seams as not worthy of study. It must be realized, however, that there are some 3 million tons of coal per square mile in a seam 3 ft. in thickness. The properties of the seams frequently vary in less than this distance, and consequently it is essential, where such a large weight of coal is in question, that a systematic study should be made.

The survey has shown that the properties of coals in certain coal fields change systematically, and it is possible to plot on a map the percentage of volatile matter and tar produced on carbonization, &c., and thus reduce the number of points at which seam sections are obtained. In other areas it is necessary to make a much more detailed study. It will be recognized at once that the economical utilization of coal depends upon the complete knowledge of its properties in any particular point in the coalfield. It is becoming increasingly important that all connected with the utilization of coal should follow the work of the Survey.

THE NEWS—*continued.*

It is not possible for the Coal Survey to do more than generalize upon the variations which are occurring, and the collieries are becoming alive to the need for analysis of the coal seams they are winning in order to detect minor variations. The survey of a seam is not considered complete until consignments selected with the greatest care from the coalfield have been examined in the large-scale units at the Fuel Research Station. In this way the properties of the coal as regards gas-making, low-temperature carbonization, and hydrogenation are investigated. This study makes it possible for those engaged in the utilization of coal to translate the variations found in the laboratory into large-scale practice.

Dr. Sinnatt then described the experiments which have been conducted on hydrogenation of coal and tar at the Fuel Research Station. Much of this work was mentioned in the William Young Memorial Lecture which Dr. Sinnatt delivered to the North British Association of Gas Managers at Paisley in September last.

In the concluding portion of his lecture Dr. Sinnatt dealt with the cleaning of fine coal. He pointed out that at the Fuel Research Station the vacuum flotation method has been considerably improved, for the treatment of certain coals, by the addition of coagulating agents which cause the precipitation of the fine impurities which may be otherwise carried over with the clean coal. In the vacuum flotation process the coal separates as a froth which, when the pressure is adjusted to atmospheric, collapses and yields a product which drains rapidly to 16-22% water. In this process Dr. Sinnatt said that all coals do not act alike and this was the reason why the method has fallen into disuse.

British Industries Fair.

Admission Arrangements.

From 1926 to 1932 H.M. Government granted £25,000 to be spent on publicity for both sections of the Fair. This grant was withdrawn for the 1933 Fair as a result of the urgent need for economy in public expenditure.

To maintain the necessary publicity, a Joint Fund administered by a Joint Committee was then established. The London Section, following much Continental practice, secured its quota by making a 2s. charge for admission, but Birmingham's arrangements were too advanced to permit a similar departure from the previous practice.

For the 1934 Fair, however, a change must be made, primarily to provide this contribution from Birmingham, but also to establish a common system for admission to the two sections of the Fair. These new arrangments follow those for London except for the public and are:

(1) Home and overseas trade buyers will be charged 2s. for a badge admitting the holder to both sections, Birmingham and London, throughout the Fair period. Trade buyers can only purchase badges at the Fair and on presentation of their trade card or of the invitation ticket issued by the Fair Authorities.

The effect in London has proved entirely satisfactory. Gangways were not overcrowded by members of the public who had managed to obtain buyers' tickets of admission. The attendances of real buyers seemed to be unaffected, and the London exhibitors have expressed satisfaction.

(2) Buyers' badges cannot be purchased by exhibitors for issue by them to their customers and/or clients.

This entirely nullifies the Birmingham arrangement for exhibitors' admission tickets at 6d. for each one used. Distribution and duplication difficulties are avoided, and exhibitors saved much expense since otherwise they would find it difficult to refuse requests for badges.

(3) The public will be admitted all day at 2s. each. Works parties on Saturday, Feb. 24, at 1s. each.

This is exactly as it was in the 1933 and other Fairs, so that the attendance of the public is not affected.

Westminster Lighting.

At the last meeting of the Westminster City Council the Traffic and Public Lighting Committee submitted a report reminding the Council that under their new contract with the Gas Light and Coke Company the improvements in the public gas lighting of the City were to be carried out by the Company at a more or less uniform rate of progress or as might be mutually agreed between the Council and the Company, and were to be completed within three years from June 16, 1932. The programme for the third instalment of the improvements, which was reported to the Council in October last, was nearing completion, and they had now approved a programme for the fourth instalment, consisting of the conversion of 180 c.p. lamps to 300 c.p. in 36 streets, including the fixing of the new type of lantern and new columns or brackets where necessary.

Rugby Street Lighting.

Gas Wins the Day.

After lengthy argument, the Rugby Town Council adopted the recommendation of the Highways Committee that the Rugby Gas Company be given the contract for street lighting of the whole of the borough for the seven-year period from Oct. 1 next. An improved system is to be carried out.

It was explained that the street lighting of the borough was controlled by six separate agreements, five of which were in respect of recently-added areas. The main agreement, it was stated, expires in September next.

Two proposals were submitted, one from the Rugby Gas Company, which holds the present contracts, and is prepared to cancel those which still have some time to run, and to light the whole of the streets for a total of £2882 a year, and the other from the Borough Electricity Department, which is prepared to light the old area only at a cost of £3645 16s. 4d. a year. Of this £3645 16s. 4d., the sum of £895 is for loan charges on the capital expenditure involved. To the £3645 16s. 4d. would have to be added £748 2s., the estimated cost of gas lighting in the outer areas, making a total of £4393 18s. 4d. By the adoption of gas for the whole area the saving shown is £1511 17s. 10d. per annum.

How Meters are Made.

Members of the Scottish Junior Gas Association (Western District) visited the Milton House Works of Milne's Meters, Ltd., at Edinburgh, on Saturday, Jan. 27. The works were in full operation for the afternoon.

The visitors were first taken to the brass foundry and to the brass finishing shop. In the latter, machines were shown in operation on the manufacture of meter component parts. The parties then visited the press shop, where meter stampings were being produced, and they spent some time in the assembling shop, where different types of meter were in course of construction. The machine shop was inspected. Here the members saw wheel cutting machines and index making in operation. The proving shop was also visited, and meters were seen being tested.

Mr. William Gordon, the Chief Inspector of Gas Meters, arranged for his Department to be on duty, so that the visitors could examine the meters passing through their final test before being sealed.

On the invitation of the Directors of the Company, the members proceeded to Messrs. Ferguson & Forrester's, where they were entertained at tea. Mr. J. R. Little, a Director of the Company, welcomed the visitors, and Mr. A. Tran expressed appreciation of the arrangements made for their visit and of the kindness of the members of the staff in explaining the various processes.

Oil from Coal Plant.

An official statement has been issued by Imperial Chemical Industries, Ltd., in regard to the progress in the erection of the petrol plant at their Billingham Factory.

Work was started on the project as soon as practicable after the announcement by Sir Harry McGowan in July, 1933, of the intention of I.C.I. to proceed with the scheme, and has continued steadily since that date. At the present time the greater part of the site development and foundation work has been completed, and erection of steelwork is now under way.

Orders for nearly all the plant and machinery have already been placed with manufacturers, and work on these orders is in full swing, giving employment to many men in the big industrial centres, particularly Tees-side, Sheffield, and the Clyde.

Of the men required directly by I.C.I. on the site at Billingham, a very large number are already engaged, and the rest will be taken on as required in accordance with the Company's usual practice through the local Labour Exchanges.

The work is progressing strictly according to the programme laid down, and the complete plant is expected to be in operation early in the spring of 1935.

A TECHNICAL SIGNPOST : TO THE "JOURNAL" :

Vol. 204, October-December, 1933

An event of importance in the development of the use of compressed coal gas is the opening of a gas compressing and public gas filling station—the first of its kind in the country—at the works of the Chesterfield Tube Company (p. 585). The compression plant consists of a Bryan-Donkin four-stage compressor, which delivers 1000 c.ft. of free gas per minute. This gas is charged into large storage cylinders from which the portable cylinders can be supplied. The running costs of the plant are given as 11d. per 1000 c.ft., which, with a capital charge of 2½d., makes a total charge of 1s. 1½d. per 1000 c.ft. Some interesting information is given by the above Company regarding the tests which have been made to determine the safety of the portable cylinders now being used. One of the dangers of the use of high-pressure cylinders has been the possibility of a serious explosion if the cylinder be subjected to a violent shock; but from the following tests it will be seen that this difficulty has been successfully overcome by the use of new alloy steels. The tests applied were: (1) After a test pressure of 4500 lbs. per sq. in. had been applied the pressure was increased until the cylinder burst, this being at about 7000 lbs. per sq. in. The cylinder fractured without any fragmentation of the metal. (2) A cylinder was charged with gas to a pressure of 3000 lbs. per sq. in. and dropped 30 ft. without apparent damage. A weight of 56 lbs. was then dropped from the same height upon a horizontal cylinder—again without damage being caused. (3) A bullet from a service rifle was fired through a cylinder at a range of 25 yards. A clean hole was penetrated through the metal, but no explosion was caused. (4) Finally 4¾ lbs. of cordite were detonated inside a cylinder. The cylinder walls were disrupted, but there was no fragmentation of the metal.

Experience with the compression of coal gas has shown that where the compression is carried out in the absence of water, the gas is dehydrated and certain gums are deposited with the water (p. 65). In a cylinder taking a daily charge of 300 c.ft. per day approximately ⅓ oz. of gum was deposited in twelve months. It was, however, only after continued use for 7 to 8 months that the accumulation of gum began to cause difficulty with the reducing valve of the cylinder. The remedy proposed is to use an aqueous lubricant.

Compressed Gas for Domestic Supply.

An interesting report upon the use of compressed gas comes from Denmark (p. 583). For two Danish islands, which are not supplied with town gas, a scheme has been successfully organized for the supply of cylinders of compressed gas. The cylinders have a capacity of 380 c.ft. of free gas at a pressure of 200 atmospheres. Fittings are sold or hired to the householders, and there is also supplied a special reducing valve for controlling the flow of gas from the cylinders. The cylinders are distributed by lorry, and on one island the consumption averages 42 cylinders per consumer per annum. The price charged is 6s. 4d. per 1000 c.ft., which may be compared with the fact that the price of gas in Denmark ranges from 2s. 6d. to 7s. per 1000 c.ft.

General Notification of Gas Referees.

A revised edition of the General Notification of the Gas Referees has been issued, and is to come into force on Jan. 1, 1934 (p. 711). There are a considerable number of modifications, out of which the following are selected: (1) Artificial heating of rooms for recording calorimeters must now be thermostatically controlled. (2) Another inferential recorder—the Simmance calorgraph type R—has now been approved as an alternative to the Sigma instrument. (3) The volume measurement of the water from a calorimeter is to be replaced by actual weighing—a suitable apparatus for this purpose having now been devised. (4) An important alteration is made with regard to testing for hydrogen sulphide. In place of freshly moistened lead acetate papers the dry slips may now be used.

Carbonization.

Despite the obvious importance of the subject, very little is known regarding the extent of leakage of gas from the various types of retorts now in use. Only a few isolated figures have been published from time to time, and the recent work of Clucas on this subject is very welcome (Nov. 1 Supp., 6). His experiments are confined to horizontal retorts, and were carried out at the works of the Leeds Gas Department. Two methods of measurement were adopted: (*a*) The determination of the extent to which the CO_2 content of waste gases is below the theoretical value calculated from the composition of the producer gas. This gives a measure of the leakage of coal gas. This involves very exact sampling and gas analyses, and is essentially work for the research chemist. (*b*) The direct measurement of the leakage of air from the retorts. The first method gave leakage values from 0·7 to 2·7 therms per ton from retorts whose age varied from 1500 to 2700 days. In these experiments the pressure in the mouthpiece varied from 0·05 to 0·2 in. water gauge. The effect of increased pressure was investigated. With normal working as above a loss of 1·1 therms was found; by sealing the anti-dip pipes on one side this loss increased to 3·6, and when sealed on both sides to 11·1 therms. In the latter case a pressure of about 1 in. was obtained. That the leakage is always considerably greater after scurfing is well known, and in these experiments it was found to increase from 0·6 to 3·8 therms when four retorts were scurfed together in a setting of ten retorts.

The direct measurement of leakage was effected by passing air in to a sealed retort and noting the rate of supply necessary to maintain a constant pressure. A "leakage index" is calculated, this being the number of c.ft. of air leakage for each hundredth of an inch pressure in the retort. This is correlated with the loss in therms per ton, an index of 2 being approximately equivalent to a loss of 0·8 therm per ton. The following results were obtained:

No. of Retorts.	Leakage Index.
37	1 and less
28	1–2
5	2–3
6	Over 3

The effect of scurfing was to raise the index of an individual retort by 40 to 150 times. In the ensuing discussion on this paper it was mentioned that the direct method of measurement was a routine operation of the Gas Light and Coke Company and that the results were similar to those found at Leeds. The influence on the leakage of various methods of hot patching, spraying, &c., after scurfing was examined, but with rather negative results. The loss of gas at Leeds by leakage is, in general, surprisingly low, and this must be attributed largely to the careful maintenance of uniform pressure conditions in the retort.

Details of several new carbonizing plants have been published. The largest of these is the installation of Woodall-Duckham intermittent vertical chambers at Tottenham, which was recently opened by the Duke of York (p. 767). There are two benches, each with four settings, each setting having six retorts and its own producer, recuperator, and waste gas flue. The chambers are 21½ ft. high, 10 ft. long, by 1 ft. wide at the bottom and carbonize a charge of 3¾ tons in 11 hours. The capacity of the plant is given as 392 tons or 5·2 million c.ft. per day. Combustion takes place in horizontal flues, and the secondary air may be added in stages if required.

At Darwen, the old installation of Munich chambers—the only example in this country—has been replaced by Drakes' vertical retorts (p. 327). Four settings of four retorts have been erected. The Woodall-Duckham Company announce that new plants for Nottingham—18 of the 103-in. retorts—and for Birkenhead—16 of the 103-in. retorts—are to be erected (p. 879). In each case provision is being made for burning breeze in the producers. At St. Ives (Cornwall) an installation of the smallest type of "W.-D." retort (44-in.) has been constructed (p. 209). The single bench has three retorts carbonizing 129 tons of coal per day.

In a paper on the heating of horizontal retort settings reference is made to the possibility of increasing the throughput by adding part of the secondary air under the main arch of the setting (p. 781). This arrangement permits of high flue temperatures without incurring ex-

cessive temperatures in the combustion chamber. The average temperature of the setting is increased, and a higher throughput should be obtainable. It is claimed that by increasing the flue temperature to 1250° C. the throughput can be raised by 40%, but no actual large-scale results were given in support of this. In the discussion on the paper several speakers, who had apparently had experience of this method of heating, were doubtful whether any such increase in throughput was possible. Another claim was that the fuel consumption per ton of coal could be decreased. It is a simple matter, however, to show that unless the throughput is increased by some 50% the fuel consumption per ton of coal will be increased. A setting of this type is being investigated at the Fuel Research Station, and the results obtained should be of considerable interest.

Domestic Fuel from Coke Ovens.

The possibilities of the production of a domestic fuel in coke ovens at either high or medium temperatures is of particular interest to the coke oven industry, and there is considerable activity in this direction. Dr. Koppers has described a process which is being worked in France for the production of a medium-temperature domestic fuel (p. 267). A blend of coking coal and a coal which has been preheated to remove its coking power is carbonized in narrow ovens. The use of preheated coking coal is apparently necessitated by the absence of a suitable non-coking coal in the locality. The coal for blending is preheated in a rotary kiln (the temperature of which is not specified), and the resulting powdery semi-coke is then mixed with the coking coal. It is specified that the width of the ovens should lie between 11·8 and 13·8 in., the smaller width being preferable for more rapid carbonization. The carbonizing temperature is apparently about 700° C. and the time of carbonization about 18 hours.

The product—which is known as "Carbolux"—is stated to be a good fuel for the domestic open grate, although it is presumably being used on the Continent for closed combustion stoves, for which the usual low-temperature product is hardly suitable. The product is obtained in large pieces sometimes equal to the whole width of the oven. For Continental markets this property is a definite advantage, but it has not the same value in this country. The plant is so arranged that by raising the temperature it may be used as a normal high-temperature process. The above plant, which was erected for the Compagnie des Mines de Bruay at the Pas-de-Calais, has been operated satisfactorily for a couple of years. The blending of low-temperature fines and coking coal is not, of course, novel, and several patents are existent in this country which cover, generally, the same treatment. It will also be recalled that provision has been made in the new coal blending plant of the Gas Light and Coke Company for the use of a low-temperature coke in a similar manner to reduce the swelling of strong coking coals.

A general review of the question of the manufacture of domestic fuel in coke ovens is contributed by Cerckel (p. 831). In reference to the many attempts to produce commercially low-temperature fuel, he states that, although over 2000 patents have been registered and over £12,000,000 spent on the various processes, the consumption of low-temperature fuel to-day is only 22,000 tons out of a total domestic consumption of 40 million tons of coal. In regard to the use of coke ovens for this purpose, the main difficulty lies in the low throughput of coal, and to obtain a reasonable throughput narrow ovens are necessary. Ovens as narrow as 7 in. have been used, notably on the Continent, for the production of a low-temperature fuel. An oven—the Lecoq—has now been specially designed for medium-temperature carbonization. One unit is at work at the Montrambert Colliery in France and carbonizes a charge in 9½ hours at 700° C. A further unit is being erected for the New Brancepeth Colliery. The product is stated to be a good hard coke containing from 4 to 6% volatile matter and is easily ignited.

A process for the carbonization of briquettes in vertical retorts has been patented by the Gas Light and Coke Company (B.P. 390-827) (p. 143). The retort is charged with briquettes which remain stationary until the outside layer of the briquette is sufficiently carbonized to give a hard skin, which then maintains the briquettes in their original shape. A portion of the charge is then extracted and a further supply of briquettes charged. The process is thus intermittent and is claimed to be specially suitable for making briquettes from coke breeze and pitch (90% breeze: 10% pitch).

Complete Gasification—Water Gas.

Some further details have been published concerning two complete gasification plants which are in operation in this country. The original Humphreys & Glasgow plant at Mill Hill has now been altered and improved (p. 643). High-pressure steam is used in an injector to circulate the gases through the plant, the same steam at a lower pressure serving for the gasification of the coke. An additional washer has been provided so that the tar resulting from the carbonization of the coal can be collected separately from the water gas tar produced in the later stages of the process. The following general working results are of interest:

Gas per ton of coal	53,600 c.ft.
Calorific value	340 B.Th.U.
Therms per ton	182·8 therms

Some amplification of the results previously given for the Moore complete gasification plant at Burnham-on-Sea have been published (p. 594). A gas yield of 170-180 therms per ton of coal at a calorific value of about 450 B.Th.U. is claimed.

The process is not necessarily one of complete gasification, the coke being partially or completely gasified, according to the calorific value required in the mixed gas. Financially, the plant appears to have been very successful and has resulted in a very appreciable saving since it was installed, the cost of the first plant erected being paid off in about eight months' working.

A new water gas plant (2½ million c.ft. per day) of the latest Humphreys & Glasgow type has been installed at Edinburgh (p. 582). The plant is almost entirely automatic, valve operations, charging, clinkering, steaming, back run, &c., all being mechanically performed. One man can thus supervise 2-3 units. The following results were obtained during the guarantee tests:

Lbs. carbon per 1000 c.ft.	22·88	
Lbs. coke " " "	30·60	
Inert content of gas	9·40	%
Calorific value of gas	502·2	B.Th.U.
Oil per 1000 c ft.	1·996	galls.

In a patent of Humphreys & Glasgow (B.P. 391,603) (220) an arrangement is proposed whereby steam output of the waste-heat boiler attached to a water gas set may be varied according to the demands for water gas or steam.

Refractory Materials.

Although the flaking of vertical retorts cannot be attributed to any specific cause, the Refractory Materials Committee of the Institution (Nov. 1 Supp., 9) have indicated a number of contributory factors, all of which tend—to a greater or less extent—to flaking of the silica material. These are briefly:

1. Penetration of scurf into retort materials and detachment of silica material during scurfing operations.
2. Constitutional changes in silica due to high local temperatures when scurfing.
3. Alkaline penetration, &c.
4. Steep temperature gradients and variable temperatures in flaking zone.
5. Rodding of charges and scurfing operations.

No recommendations are made as to any change in practice, but by careful control the effect of the above factors may be diminished. In regard to the attack by alkalis, it is stated that examination of the brickwork of continuous vertical retorts has shown fairly definite evidence of the attack of the refractory material by alkalis in the liquid and gaseous condition. This effect takes place in the lower part of the retort where the ash is liberated by gasification of some of the coke. The weakening of the material arising from this alkali penetration enhances the tendency to flaking.

Purification.

Several references have already appeared concerning the removal of carbon monoxide from coal gas by bacterial treatment (p. 145). By the combined effect of passing the gas first over a heated metallic catalyst and finally over activated sludge the carbon monoxide can be practically eliminated. There is a reduction of 17% in volume and an increase in calorific value of 32 B.Th.U., the process thus involving a net loss of about 8% of the thermal value of the gas. This forms a serious debit, quite apart from operating costs.

The recovery of pure sulphur from spent oxide by solution in carbon disulphide appears to be making progress in Germany (p. 704). Several new plants are under construction or in contemplation, and the process merits serious consideration by the larger undertakings in the absence of satisfactory markets for spent oxide. In a recent patent (B.P. 390,788) relating to oxide purification, there is proposed a heater for the gas entering the purifiers, from which the heating tubes may be conveniently withdrawn for cleaning and other purposes (p. 220). In another patent (B.P. 391,928) it is proposed to construct

a purifier similar to those employed on the Continent, in which the purifier box is comprised of a number of superimposed layers of oxide (p. 220). Each layer has its own inlet and outlet valve, and the flow to each layer may be separately controlled.

Tar.

While there is a considerable amount of information now available regarding the suitability of tar oils as fuels for internal combustion engines, there does not appear to be any consensus of opinion as to the characteristics required in a suitable oil. The Institution of Gas Engineers have therefore decided to examine the problem, and Dr. E. W. Smith is preparing a report summarizing existing information (p. 130).

A comprehensive account of the dehydration and distillation of tar by the Cooke process has been given by Holton (p. 331). The basis of the process is the utilization of the sensible heat of crude coal gas or producer gas for the distillation of tar. At the works of the Manchester Corporation hot producer gas is being used. This gas, generated in Trefois producers, passes through a tower down which hot tar is sprayed, and finally to a condenser. The tar—initially preheated by steam coils—is circulated between two storage tanks until it is of the required composition. Two complete circulations are required to yield a No. 1 road tar and three are required for the No. 3 road tar. Some of the light oils are retained by the producer gas, the calorific value of which is raised by about 40-50 B.Th.U. The remainder of the oil is removed in the condenser. The following figures are indicative of the results obtainable:

	Tons.
Crude tar fed	95·5
Road tar produced	80·3
Creosote produced	10·05
Water evaporated	2·35
Loss as oils in producer gas, &c.	2·8
	95·5

The process has also been extended to the utilization of the sensible heat of the gas from continuous vertical retorts, and a large-scale unit is in operation at the Partington Works. The tar is continuously circulated through the hydraulic main, being sprayed into the mains through a suitable atomizing nozzle. There are two possible methods of circulation: (*a*) Circulation of a batch of tar until it attains the required composition. (*b*) Continuous circulation with removal of predetermined quantities of tar at regular intervals, and addition of equivalent quantities of crude tar. Using the latter method on a setting carbonizing four tons of coal per day a throughput of 75 gallons of tar per day was obtained. About 80% of the crude tar is recovered as No. 1 or No. 2 road tar. Different grades of tar may be produced by cutting back the distillation with crude tar, &c., and no difficulty is envisaged in meeting any new specification which may be adopted for road tars. In regard to the application of the process to horizontal retorts, doubt is expressed whether there is sufficient sensible heat available in the foul gases from this type of retort. Several advantages are claimed for the process, of which the most important are the low initial cost as compared with the standard type of plant and the saving in fuel and labour. The process has encountered some criticism, particularly regarding its suitability for application to small and medium sized works. The majority of works now sell their tar through a co-operative scheme and thereby gain the advantage of expert technical and commercial knowledge, to which they would not have access if they treated their own tar.

Coke.

A useful review of the process of combustion in the coke fire and of the characteristics required in a suitable coke fuel has been given by Hodsman (Nov. 1 Supp., 12). Reactivity is of little value as a comparative factor, since at temperatures above 800° C. the rate of combustion is determined mainly by the rate at which oxygen can gain access to the coke surface. At lower temperatures the reaction is slower, and the "specific" reactivity of the material may influence the rate of combustion and in particular the rate and temperature of ignition. Reactivity is not readily measured at such low temperatures, and it is more convenient to determine the rate of ignition. This characteristic may vary at different parts of the surface of a single piece of coke.

The most reactive areas are naturally the first to ignite—which results in variations in the ignition point of coke which has been previously ignited. The bulk density of the coke is regarded as an important factor. Cokes of high bulk density are more difficult to ignite than those of lower density. While the reactivity has no apparent correlation with rate of ignition, the latter property appears to bear some relation to the bulk density. An example of the greater ignitability of material of low bulk density is given by the ease of ignition of cinders from a coke fire—the reactivity of which may be lower than that of the original coke. This may be due to the reduction in the rate of heat lost from the surface, owing to the low thermal conductivity of the material.

Since the major defect of the high-temperature product is the slow rate of ignition, methods of increasing the ignitability were examined. By giving the coke a coating of easily ignitable material it is more easily ignited. After examining various substances it was decided to use coal dust *plus* a suitable adhesive. The adhesive and coal dust are simultaneously sprayed on the coke, the result of this treatment being to reduce the quantity of gas required for ignition and to increase the rate of radiation immediately after ignition. Although there is a definite improvement in the value of the fuel by this treatment, its economic application on a large scale is beset with many practical difficulties.

An important contribution has been made by Birks, who describes the methods adopted by the Gas Light and Coke Company for the preparation of coke for the London market (p. 399). The hot coke from the retorts is, in general, quenched on the dry plate conveyors; but three retort houses have recently been equipped with the Fleuve system, in which the coke is transported and quenched by a current of water. For this latter system, it is claimed that the normal maintenance costs are halved, while the moisture in the coke varies from 1·5% in the sizes over 2 in. up to 6% for the ¾ in. to 2 in. sizes. The fact that the majority of the shale is present in the smaller sizes of coke is utilized to produce a shale-free coke by breaking the large coke. The fuel marketed as "Cleanglow" is a vertical coke treated in this way. This treatment of coke is also stated to give a more combustible product. The coke for sale is screened into five sizes:

Horizontal and Vertical Coke.	Oven Coke and Intermittent Chambers.
Over 2 in.	Over 1¾ in.
1½–2 in.	1⅛–1¾ in.
⅝–1½ in.	⅝–1⅛ in.
⅜–⅝ in.	⅜–⅝ in.
Under ⅜ in. (Breeze)	Under ⅜ in. (Breeze)

It is found that excessive wear takes place with rotary grizzly screens, and these are being replaced by vibratory screens, some of these being of the resonance type. Although a shale-free material can be prepared by the breaking of large coke, the ordinary screened coke contains sufficient shale to prejudice its use in certain appliances. The oven coke is free from this defect, since it is made from crushed coal. The shale may be removed from the coke by wet washing or by air flotation methods.

The Birtley process of pneumatic coke-cleaning has been successfully applied to the de-shaling of coke, and several units are to be installed by the Gas Light and Coke Company. Some results obtained by the use of this process are given in a paper by Holmes (p. 827), and relate to an experimental plant erected at the Southall works of the Company. By this treatment the ash content of coke nuts was reduced from 12·4% to 8·3%, the refuse containing 68·5% of ash. With two smaller sizes the following results were obtained:

Size.	Ash Before Cleaning.	Ash After Cleaning.
	%	%
½–⅝ in.	18·7	9·0
⅜–1½ in.	15·9	6·5

While the process naturally works most efficiently with closely graded material, mixed sizes such as 0-2 in. can be treated. With such material, however, the importance of maintaining a constant feed is emphasized.

Ammonia.

A further report has been issued by the Ammonia and Effluent Committee of the Institution, in which consideration is given to a number of subjects. Research work has been carried out on the biochemical oxidation of liquor (Nov. 1 Supp., 4). The oxidation of the various individual constituents of a liquor such as phenols, thiocyanates, sulphides, &c., was examined in the presence of sewage liquor. Using non-sectional bacterial filters, it was found that all oxygen absorption constituents could be completely destroyed by bacterial action so long as their concentration in the liquor treated did not exceed certain limits. For thiosulphates this limit was an oxygen absorption value of

16 to 32; for sulphides 8 to 16. A value of over 32 was obtained with phenol, thiocyanates, catechol, &c. Similar results were obtained using activated sludge. The individual constituents of liquor thus have different values as far as biochemical oxidation is concerned, and the removal of thiosulphates would be considerably more beneficial than the removal of an equal quantity of phenols. In fact, improvement in the degree of oxidation obtained by the removal of phenol is so small that a relatively costly removal process hardly appears justifiable.

An examination has been made of the possibility of removing phenol from a liquor by distillation. Both substances followed the same law—*i.e.*, the ratio between the concentration in the liquid and the vapour is a constant. In liquids containing both ammonia and phenol the volatility of the latter is reduced, and hence only a small proportion of the phenol is removed during the process of ammonia distillation. These experiments do not confirm a previous claim that the rate of distillation of these two compounds was more or less the same.

A method for the production of ammonium bicarbonate has been worked out and patented (British Patent 393,678) (603). The method employed is based on the addition of ammonia to the crude gas to raise the proportions of CO_2 and NH_3 to a point at which ammonium bicarbonate may be washed out of the gas. The additional ammonia is obtained by steam distillation of the liquor, and is added to a portion of the crude gas which is by-passed for this purpose from the main stream. This gas passes through a scrubber, where it is washed by a solution of ammonium bicarbonate. The salt eventually crystallizes from this solution and is recovered by any suitable means. There are several practical difficulties. The process is really only suitable for vertical retort gas with a high CO_2 content and is theoretically inapplicable to a gas containing less than 1·6% CO_2. In practice this figure would probably be considerably higher in view of the slowness of the reaction and the difficulty of efficient absorption of the bicarbonate. Results of tests on the fertilizing value of ammonium bicarbonate are still awaited and will doubtless determine whether the production of this compound is worth further consideration.

Gainsborough's New Gas Plant

Inauguration of Woodall-Duckham Vertical Retorts

On Wednesday last Capt. H. F. C. Crookshank, M.P. for Gainsborough, officially inaugurated a new installation of Woodall-Duckham vertical retorts at the works of the Gainsborough Gas Department.

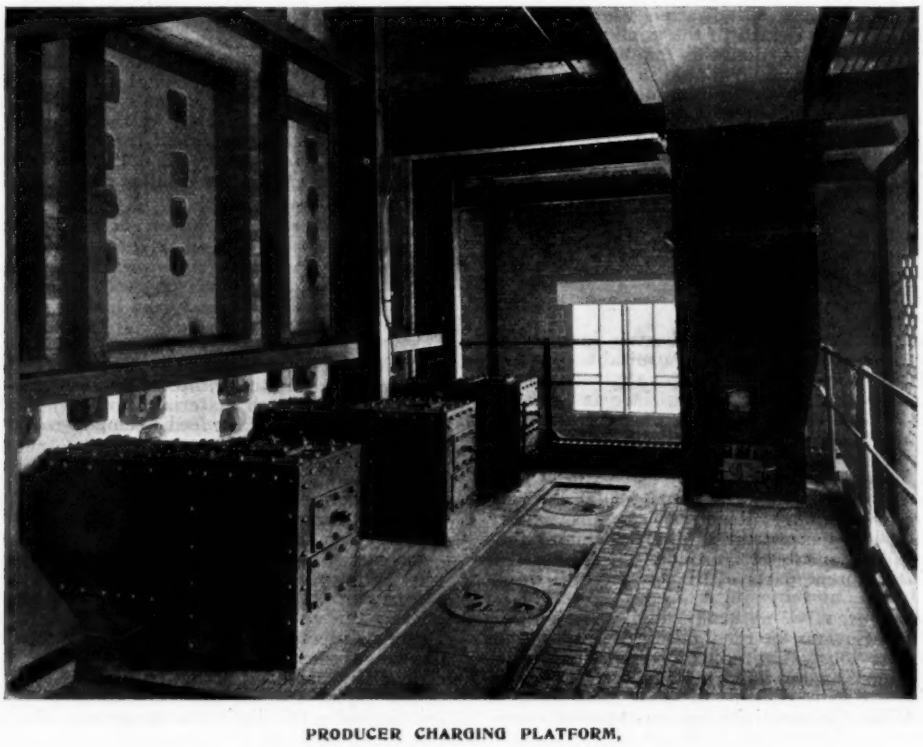
In a booklet prepared for the occasion it is explained that in the year 1824 it was decided to light the town of Gainsborough with gas, and Mr. John Malam was instructed to erect a gas-works, and a twenty-one years' contract was entered into to erect lamp posts not more than fifty yards apart, and lay pipes only to the outer sides of the houses. Mr. Malam was to keep in repair the property of the gas-works, and replace and repair the highways. Some time after completion, the works were transferred from him to certain parties in the town who were known as the "Proprietors of the Gainsborough Gas-Works."

The Gainsborough Gas Act, 1856, provided for the improvement and enlargement of the works, and the transfer of the Undertaking from the "Proprietors" to the "Gainsborough Gas Company" with an authorized capital of £20,000. During the period the Company owned the undertaking, from 1856 to 1899, a considerable advance was made, for it was then that Gainsborough became an engineering centre. In forty years the population increased from 7000 to nearly 17,000, and between the years 1880 and 1895 the gas-works were completely rebuilt.

In 1899 the Urban District Council purchased the undertaking for £87,737, and subsequently further loans have been raised, making a total capital of £108,217. Of this sum, £72,717 has been repaid, leaving an outstanding debt of only £35,500 on the undertaking.

The Gas Committee in 1931, when considering some necessary expensive repairs to the existing retort house, came to the conclusion that gas could be more efficiently and economically produced by a modern plant. It was considered that the plant erected between 1880 and 1895 had come to the end of its useful life, and that in view of the low outstanding debt a further capital expenditure was warranted.

A careful investigation followed, and other works equipped with modern plant of different types were inspected. The works are situated in a residential district,



PRODUCER CHARGING PLATFORM.

and cleanliness in operation is thus considered an important factor; the fact that the site is bounded on all sides by highways prevents any extension thereof. A plant therefore was required needing small ground space. It was finally decided to erect a continuous vertical retort installation, which would meet these needs.

Specifications and drawings were prepared and tenders called for, one condition being that any materials or labour which could be secured on a competitive basis were to be obtained in Gainsborough. The Council's Gas Engineer, Mr. Chas. E. Byrt, was responsible for the preparation of the specifications and drawings for the scheme, and the construction was carried through under his personal supervision.

The new installation consists of one bench containing six latest type upwardly heated Woodall-Duckham continuous vertical retorts, and is capable of carbonizing 26·4 tons of coal and of producing 548,000 c.ft. of 450 B.Th.U. gas a day. The gas used for heating the retorts is made in two producers situated at ground floor level at one side of the bench. The installation is erected in a new steel-framed brick-panelled retort house and is provided with a waste-heat boiler for the recovery of the heat contained in the waste gases from the heating of the retorts.

The retorts are of the smallest type developed by the Woodall-Duckham Company. On small works, in order to obtain maximum flexibility and efficiency of operation, it is desirable that the carbonizing plant should be divisible into a reasonable number of separately controllable units. Although the plant has a gas output of only 548,000 c.ft. a day, there are six independent retorts, so arranged that any one retort can be heated up, cooled down, or scurfed without affecting the others. In this way variations in the demand for gas can be closely met.

The retorts are about 25 ft. high, rectangular in plan and tapered to allow continuous regular descent of the coal. They are 44 in. long and 10 in. wide at the top.

The combustion of the heating gases takes place in an upward instead of a downward direction. This permits a zoning of heats which has been found to give the following advantages: Perfectly regular travel of coal; less scurf formation and less loss of time at scurfing periods; and better steaming conditions.

The Woodall-Duckham system of upward heating in vertical flues, which follows the natural flow of the hot combustion gases, is particularly simple to put into operation and to control. When the heats have once been regulated, only the producer gas and waste gas dampers need adjustment.

By the introduction of the upwardly-heating principle the temperature in the vertical combustion flues is sufficiently reduced, at the point where erosion of the silica normally takes place, to allow the retorts at this level to be constructed with perfect safety in firebrick. By the time the coal has travelled past this belt of firebrick, and enters the silica portion of the retort, it has acquired a sufficient heat to avoid the extreme differences in temperature on either side of the retort wall, which are the main cause of the erosion of silica material at this point. In this way the full advantage of silica construction as regards high throughput of coal is obtained, with a reduction in maintenance costs.

Both the side walls and the top of the bench are efficiently insulated, with the double object of improving the working conditions and saving fuel.

To supply the gas for heating the retorts two producers are provided at the retort house floor level at one side of the bench. The producers are arranged so that one producer may be shut down without interfering in any way with the working of the other producer. The gas from either of the producers may be taken to any of the retorts.

The producers are of the step-grate type and each is constructed with ample grate area for the efficient heating of six retorts as well as for burning the additional amount of fuel required for a supplementary supply of producer gas to the waste-heat boiler. The step-grate eliminates the need for clinkering. The only attention required to keep the producer fire in proper condition is a periodical pricking up at intervals of four hours or longer, depending on the class of fuel used.

The waste-heat boiler, which is of the special Woodall-Duckham horizontal natural draught fire-tube type, is designed for a working pressure of 100 lbs. to the sq. in.

The boiler is fitted with all the necessary steam and water mountings and fittings, including a high and low water alarm. A single cylinder direct acting feed water pump is provided for feeding the waste-heat boiler, with a steam operated feed water injector to act as stand-by. The feed water pump is automatically controlled by means of a Thermo-feed regulator.

The whole of the steam requirements for retort and producer services and for actuating the engine and pumps are supplied by the waste-heat boiler, and there is a considerable surplus available for other works purposes.

The improved labour conditions under which the retort house duties are carried out, when using this system of continuous vertical retorts as compared with the older system of horizontal retorts, are very striking. Not only does the new installation give greatly improved results per ton of coal handled, together with uniform quality and composition of gas produced, but the absence of smoke and steam and arduous labour is thoroughly appreciated by the workmen as well as those who reside near the gas-works.

A noticeable feature of the plant is the freedom of access to all parts of the bench, with generous headroom under the settings, easy stairways, and broad gangways, all of which make for ease and comfort of working and efficient operation.

Tribute to Mr. Byrt's Work.

At tea which followed the inauguration ceremony, tribute was paid to the work of Mr. Byrt.

During the proceedings after tea the electric light in the town hall failed and the Chairman of the Gas Committee, who was speaking, remarked that that was a weakness of their competitors.

Mr. G. W. H. Pearce, Chairman of the Urban Council, presided, and extended a warm welcome to the visitors.

Mr. L. R. Smith, Chairman of the Gas Committee, said that despite the " doubting Thomases " who were against the proposal to purchase an entirely new plant, more gas was being used to-day now the new plant was running than ever before in the history of the undertaking, and they anticipated that it would effect an annual saving of £2000. The plant was cleaner and healthier in every way, and they were certain that it would allow them to conquer fresh fields.

Mr. F. B. Richards, Chairman of the Woodall-Duckham Company, said he was an optimist as far as the future of gas was concerned. He presented Mr. Smith with a silver casket as a memento of the occasion, and wished the Gainsborough Undertaking much success.

Votes of thanks were passed at the close.

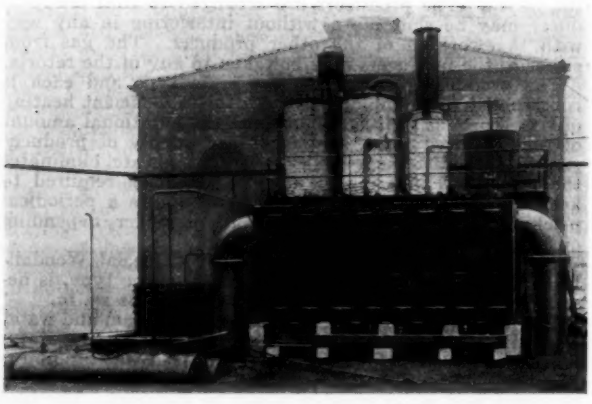
The British Legion.

The thirteenth annual report and statement of accounts of the British Legion, just issued, shows that the income during the financial year ended Sept. 30, 1933, and the Poppy Day Collections of Nov. 11, 1932 (excluding Scotland), amounted to £467,589.

The report deals fully with the activities of the British Legion in the administration of moneys contributed by the public on Poppy Day for the relief of ex-Service men and their dependents who are in distressed circumstances. It is found that distress is mainly caused through unemployment, and the Legion, for some time now, has made the finding of employment for ex-service men the most important of the activities of its members. During the year under review no fewer than 38,811 men were found work; this number includes men who still carry a disability, the result of war wounds.

The acute depression in industry and commerce has taken its toll of ex-Service men and their dependants, and there has been no falling off in the administration of " relief in kind." For this purpose 3692 voluntary relief committees have been at work during the year. The Legion has taken its part in the discussions on Disarmament, and representatives were present at Geneva, in March, 1933, to put forward the views of the Legion.

The Prince of Wales British Legion Pension Fund, raised by H.R.H. the Prince of Wales, from the sale of the Legion Book, gives to the prematurely aged ex-Service man or woman a measure of assistance during a difficult period. The needs of war pensioners continues and the Legion gives freely of advice and assistance.



BENZOLE RECOVERY AT WARRINGTON*

By

A. COOK,

Engineer and Manager of the Warrington Gas Department.

Early in 1933 it was decided to install a benzole recovery plant to extract two gallons per ton of coal from the gas at the outlet of the purifiers. The annual make of gas was 700 million c.ft. with a declared calorific value of 470 B.Th.U. produced in our Woodall-Duckham continuous vertical retort installation.

The make of gas per ton of coal at 470 B.Th.U. was 16,870 c.ft., and theoretical calculations were made to determine the effect of two gallons recovery on the calorific value, so that we could estimate the effect on the coal consumption. Having regard to the paraffin content, two gallons of vertical retort benzole were taken as 316,000 B.Th.U. To estimate the C.V. required at the inlet of the benzole washer scrubber, if this is represented by x and one gallon of benzole accounts for 34 c.ft. of gas:

The two gallons of benzole will be contained in the high C.V. gas of which there will be 15,140 c.ft. per ton.

$$\text{So } 15{,}140\,x = (15{,}140 - 34)\,470 + 316{,}000.$$
$$x = 490.$$

To make 490 B.Th.U. gas at our works the extra coal consumption was calculated as follows:

If y = the make per ton of 490 B.Th.U. gas assuming that steam in the retorts produces 295 B.Th.U gas

$$295\,(16{,}870 - y) + 490\,y = 16{,}870 \times 470$$
$$y = 15{,}140 \text{ c.ft.}$$

Thus to make 16,870 + 68 = 16,938 c.ft. of 490 B.Th.U. gas requires 16,938 ÷ 15,140 = 1·1187 tons of coal, an increase of 11·87%.

In calculating the profit we allowed for the carbonization of 5341 extra tons of coal per annum, bearing in mind that we should obtain 30 lbs. of extra coke per ton, due to the reduced steaming.

The cost of recovery per gallon of benzole from the above figures will be:

	d.
0·0593 ton of coal, less coke, residuals, &c., at 7s. 6d. per ton	5·34
Labour	0·11
Steam	0·48
Water	0·003
Gas oil	0·30
Interest and depreciation	0·51
Allowance for repairs	0·20
	6·943

The products being one gallon of 80% benzole.
30 lbs. per ton extra coke − 15 lbs. of coke.

The contract was placed with the Chemical Engineering and Wilton's Patent Furnace Company, Ltd., and includes a Wilton's patent static washer scrubber of 3 millions capacity and a benzole recovery unit of their modern type. The 24-in. gas connections were made to our mains under pressure and without cutting off the gas. The plant was arranged outside the building of the station meter, and the stills are arranged on a platform so that the circulation of oil is maintained by one pump.

A tank of 12,000 gallons capacity serves to store the benzole recovered, and one of 500 gallons is used to collect the old wash-oil which should be removed at a specified rate to prevent sludge formation. In our case we have no outlet for the spent wash-oil, as our water gas plant is not in continuous use. We are quite aware that if we put in new oil corresponding to about one gallon for three or four gallons of benzole made, we shall keep free from sludge, but for the present we find it economical to run until sludge forms in the oil cooler. The sludge is quite easily removed when necessary by steaming out the pipes.

Tar Distillation Plant.

We have our own tar distillation plant and will shortly be preparing a wash-oil of our own from the creosote and green oil fractions.

The arrangement of the plant is very compact. There is only one prime mover—in our case, a horizontal steam engine with governor operating the static washer scrubber and the oil circulation through the direct-coupled pump. The wash-oil used for the present is gas oil. The total quantity in circulation is 2000 gallons contained in the washer balance tank, heaters, and still. The rate of circulation is 300 gallons per hour. The debenzolized oil passes through the washer scrubber and is picked up and showered by the pumps opposite each bay, continuously wetting the tubular filling with which the washer scrubber is packed. The tubes are ¾ in. diameter, and each is fitted with a twisted strip, so that the gas is divided into a great number of small streams, each passing through the wetted tubes with a spiral motion.

The showers are of Wilton's patent unblockable type and spread a heavy rain of wash-oil over the tubes at about 600 gallons per hour in each bay. The oil reaches the outlet and, containing about 4·5% of benzole picked up from the gas and the rich oil, runs through a balancing or make-up tank of 750 gallons, from which it is picked up by the pump and delivered to a "V" notch overhead feed tank. From here it gravitates through the oil to oil exchange heater and reaches 60° C. before entering the steam preheater.

The steam heater raises the temperature to 130° C., our steam supply being at 60 lbs. per sq. in. The hot oil goes into the top section of an eight-tray Wilton still, and is completely debenzolized. About 9·5 lbs. steam per gallon of benzole is used. The debenzolized oil gravitates from the still through the exchange heater at 79° C. to the oil cooler, which is of the atmospheric rack type with water sprinkled over the outside of the pipes. The oil returns to the washer-scrubber at a temperature of 3° to 5° F. above the gas temperature at inlet. This completes the circuit of oil.

Returning to the stripping still, the vapours given off contain all the benzole and a little wash-oil and naphthalene vapours. These pass into the fractionating column and are divided into a product of 80% at 120° C. benzole and residue, which is about ⅛ of the bulk of the benzole and contains about 1/100th part of the hydrocarbons taken out of the gas, the other 99% removed from the gas being the high-test benzole sold. The quality of the benzole is maintained constant by a thermostat, which keeps the vapours at 83° C.

Guarantees Exceeded.

The guarantees given by the contractors were to recover two gallons of 70% to 75% benzole per ton of coal, with a circulation of 350 gallons per hour. Actually, the plant recovers 2-3 gallons of 80% benzole with a circulation of 300 gallons per hour, in all respects giving us a comfortable margin.

The entire plant works smoothly and gives no trouble. We have made a test to check the theoretical calculation of the drop in calorific value by using two Boys calorimeters, one at the inlet and the other at the outlet of the plant, the difference being an average of 16 B.Th.U. The increase of coal consumption has not yet been checked, but there is no reason to expect this to be different from the theoretical amount estimated.

Much has been said about the doubtful economy of recovering benzole from vertical retort gas, and usually the drop in calorific value of the gas is over-estimated.

Judging by previous publications, many plants are allowing a large part of the recovered benzole to be lost in the naphthalene fraction. Our object has been to get into the salable product practically all the hydrocarbons removed. This is a function of the still and fractionating column and of the efficiency of the washer scrubber, each playing their part in achieving the desired result.

* A paper before the Lancashire Commercial Section of the Manchester District Association of Gas Engineers.

The Washing of Gas*

By H. Hollings, M.Sc., A.I.C., and L. Silver, B.Sc., A.R.C.S., D.I.C., A.I.C.

I. Introduction.

A few years ago we began in the works and laboratories of the Gas Light and Coke Company a general investigation of the processes of gas purification, in connection with which it was felt that the application of scientific methods had not then advanced to the same extent as in the field of coal carbonization. It soon became apparent that, quite apart from any research upon new types of processes (with which we are not concerned in this paper), a systematic study of the efficiency of existing plant and processes was necessary in order to deal satisfactorily with the larger quantities of gas being made in the carbonizing plants.

Broadly speaking, the processes are those of condensation or cooling in which the water and most of the tar are removed from the gas, together with a part of the ammonia and other impurities, followed by washing with aqueous liquor (or water) for the completion of ammonia extraction. This in turn is followed by the removal of hydrogen sulphide by oxide of iron. These may be regarded as the primary processes of gas purification in the sense that they represent the least that must be performed if a gas undertaking is to fulfil its statutory obligations. In the larger and more modern works there are, of course, other processes such as washing for removal of naphthalene or benzole, tar fog precipitation, and gas dehydration.

The investigations which we began were concerned mainly with what we have called the primary processes, although some of the results described below have a very direct application to the other processes of gas washing, and indeed, we hope, to similar processes in other industries. It soon became apparent that the efficiency of any of these processes was very dependent upon the efficiency of the one preceding it. For example, the amount of hydrogen sulphide to be removed by oxide of iron depends in some measure upon the amount removed by the aqueous ammonia liquors, and the process of removal is influenced by any ammonia or tar which may slip past the washers. Similarly the completeness of ammonia removal in the washers depends upon the proper lowering of gas temperature and removal of tar in the condensers. Reference is made to this circumstance in order to make it clear that the first stage of the main investigation was necessarily a study of the condensation process. The results of experiments in connection with condensation have been published already by one of us in collaboration with S. Pexton.[1]

In this earlier paper attention was also directed to the costs of the gas-washing process in relation to the costs of sulphate of ammonia manufacture. It will be realized by all those familiar with bye-product ammonia manufacture that the work described in the present paper has received considerable stimulus from the urgent need for reduction of manufacturing cost.

Notwithstanding the particular interest of this work in our own Industry, and more especially at the present time in ammonia recovery, we shall attempt to deal with the matter in general terms partly because we found it necessary for our purpose to solve the problem as a general case and partly because we believe the results will be of wider interest.

The term *gas washing* is here used to signify a process in which one constituent of a mixture of gases is removed therefrom, either wholly or in part, by bringing the gas into intimate contact with a liquid which will preferentially absorb the constituent either by solution or by chemical combination. Plant units whose principal function is to remove a constituent in this way are known as washers or scrubbers, the term *washer* being sometimes restricted to apparatus in which the gas is caused to bubble through the liquid, while in scrubbers the gas is brought into contact with wetted solid surfaces. In these papers, however, the term *washer* is used in a general way to cover all classes of apparatus in which the washing process is carried out.

II. General Principles Relating to Gas Washing.

Partition Factor.—A soluble constituent of a gaseous mixture in contact with a liquid absorbent distributes itself so that part is in the liquid phase and part remains in the gas. When the two phases are in equilibrium, a definite relation exists between the concentrations of the constituent in the gas and liquid phases which may be expressed by the ratio of these concentrations measured in suitable units. This ratio is known as the "partition factor," and can be put in its simplest form by expressing the concentrations in both phases in terms of parts by weight per unit volume, so that it becomes a dimensionless number independent of the particular system of units chosen. The partition factor is used in this form throughout the subsequent discussion and is denoted by k, so that if c_g and c_l represent the concentrations in the gas, and liquid phases respectively, measured in parts by weight per unit volume, then

$$k = c_l/c_g \text{ or } c_l = k.c_g.$$

The value of the partition factor depends on:

1. The nature of the absorbable constituent.
2. The nature of the absorbent.
3. The temperature of the system.
4. The concentration of the constituent.
5. Mutual action between the constituent and other constituents in the liquid and gas phases.

Under practical conditions where equilibrium may not be reached the partition between gas and liquid also depends on:

6. The time of contact.
7. The condition, distribution, and extent of the surface of contact.
8. The relative proportions of gas and liquid.
9. The velocities of liquid and gas.
10. The degree of turbulence in the two phases.

For all cases of simple solution unaffected by dissociation or association Henry's Law applies, and at any fixed temperature the partition factor is a constant unaffected by concentration. If chemical combination with the solvent takes place, the law may or may not apply. Thus, for the solution of ammonia in water, at any one temperature there is a constant proportion between the concentration of ammonia in the gas phase and the ammonia present as such in the solution. Furthermore, there is a constant proportion between this ammonia in solution and its hydroxide, NH_4OH, so that the law applies to the sum of these. It is true that a part of the ammonium hydroxide is ionized, and this part is not directly proportional to the concentration, so that, when the whole of the ammonia in solution is considered, the law is not followed strictly; but for such solutions as ammonia, carbon dioxide, or hydrogen sulphide in water, the ionization is small and the deviation is negligible over limited ranges of concentration. When these gases are simultaneously absorbed, as in the removal of ammonia from coal gas, combination also takes place between the dissolved constituents; but, if the proportions of these in the gas are unchanged, the variations in k are small, and it is often permissible to assume approximate agreement with the law in order to simplify practical problems.

The value of the partition factor for a given combination at a given temperature is an empirical quantity and must be obtained either experimentally or from published data unless Raoult's Law applies, when the partition factor can be calculated from a knowledge of vapour pressures and molecular weights.

Minimum Quantity of Absorbent for Complete Washing.—It is obvious that if the maximum absorption is to be effected with the minimum quantity of washing liquid, the counter-current principle must be employed.

The minimum quantity of liquid required in an ideal counter-current washer may be calculated as follows:

If the concentration of solute in the entering gas is G_o, and in the issuing gas G_1, and if the fraction of the solute that passes unabsorbed through the washer be S so that $G_1/G_o = S$, the amount absorbed from unit volume of the gas is equal to $G_o - G_1$ or $G_o(1 - S)$.

This must equal the amount absorbed by the liquid so that

$$G_o(1 - S) = qL_1,$$

where q is the quantity of washing liquid per unit volume of gas and L_1 the concentration of the solute in the liquid leaving the washer.

To remove a given amount of constituent, it is evident that the smaller the volume of liquid used the higher must be its final concentration. The most concentrated

* From a paper read before a meeting of the Institution of Chemical Engineers, Jan. 31, 1934.

[1] Trans. Inst. Gas E., 1929-30, **79**, 257.

possible solution is that in which the liquid is in equilibrium with the entering gas—*i.e.*, $L_1 = kG_0$.

Hence, eliminating L_1, $G_0(1 - S) = qkG_0$ or $1 - S = qk$.

The minimum quantity of absorbent, therefore, that is required to absorb all but the fraction S is given by

$$q = (1 - S)/k.$$

It follows from this that the minimum quantity of liquid necessary to effect complete absorption is given by

$$qk = 1 \text{ or } q = 1/k.$$

Rate of Absorption.—So far the discussion has dealt solely with the relations between liquid and gas when these are in equilibrium. These, however, are not the conditions in a practical washer, where the two phases are in contact with one another for a limited period and at a limited surface. The nearness of approach to equilibrium is conditioned by the time and surface available, and also by the rate at which absorption takes place, and a study of the factors that influence this rate of absorption is essential to the proper understanding of the washing process.

This problem has received the attention of investigators for many years, notably F. Hurter,[2] who showed that the rate of absorption of a gas by a liquid is proportional (*a*) to the area of contact between the phases; (*b*) to the pressure of the gas; and (*c*) to the time of contact. The product of these three quantities he designated the number of "units of contact," which he regarded as a measure of the absorbing capacity of a given apparatus.

Later investigators showed that the rate of absorption was in general not proportional to the pressure of the solute in the gas phase, but to a "potential factor" depending on the difference between the actual conditions and those of equilibrium between gas and liquid. There was a divergence of opinion, however, as to how this "potential factor" should be expressed. Lewis[3] and Whitman and Keats[4] regarded it as the difference between the partial pressure of the solute in the gas and the partial pressure in equilibrium with the liquid; on the other hand, Donnan and Masson[5] and Van Arsdel[6] express it as the difference between the concentration of solute in equilibrium with the liquid and the actual concentration in the liquid.

It can be shown that these two formulations are equally applicable when the absorption follows Henry's Law, for they can be represented by

$$(a)\ p_g - \frac{c_1}{H} \text{ and } (b)\ H.p_g - c_1,$$

where p_g = partial pressure in the gas, c_1 = concentration in the liquid, and H is the partition factor expressed as the ratio of concentration in liquid to partial pressure in gas. But

$$p_g - \frac{c_1}{H} = \frac{1}{H}.(H.p_g - c_1).$$

The two formulations are thus proportional if H is constant. It, however, H is variable, they cannot both fit the facts.

These theoretical conceptions have been clarified considerably by the work of Whitman,[7] and that of W. K. Lewis and his collaborators of the Massachusetts Institute of Technology. In what follows below an attempt is made to re-state the two-film theory developed by the above workers in a form which permits of more ready practical application.

It is assumed that exchange of solute between gas and liquid is so rapid at the actual interface between the phases that they are substantially in equilibrium at all times. The rate of absorption, therefore, is regulated by the rate at which the solute can travel to and from the interface. When there is relative motion of the two fluids, it is considered that mixing in the main body of the gas or liquid is brought about so rapidly by convection that the concentration of the solute therein is practically uniform. As the interface is approached, however, the amount of convection normal to the interface diminishes until complete lack of motion in this direction is reached very close to the interface. The effect of these conditions on the absorption is almost exactly simulated if we regard each fluid as consisting of a thin film adjoining the interface in which no convection currents occur, together with the main body of the fluid in which mixing is complete and composition is uniform in a direction normal to the interface. The analysis of the problem is made much simpler by this assumption which is sufficiently near the truth to give an accurate correlation of the experimental data. Through these non-convecting films transfer of the solute can occur only by diffusion, and it is the thickness of the films and their resistance to diffusion that control the rate of absorption.

The rate of diffusion and hence the amount of solute transferred is proportional to the difference of concentration between the two sides of the film—*i.e.*, between the main body of the fluid and the interface. The effect of the films on the rate of transfer may be represented by co-efficients of film conductivity or transfer, k_g for the gas film and k_1 for the liquid, so that if

W is the weight of solute transferred,
A is the area of interface,

G_g and G_i are the concentrations of solute in gas in the main body and at the interface respectively,

L_i and L_1 are the concentrations in liquid at the interface and in the main body respectively,

dW/dt is the rate of absorption,

and $\frac{1}{A} \cdot \frac{dW}{dt}$ is the rate of absorption per unit area of interface, then

$$\frac{1}{A} \cdot \frac{dW}{dt} = k_g (G_g - G_i) = k_1 (L_i - L_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

The co-efficient of film transfer thus represents the weight transferred in unit time across unit area of film when the concentrations on the two sides of the film differ by unity. The concentrations may be expressed in any convenient units. It has been customary to express gas concentrations as partial pressures and liquid concentrations in grammes per c.c. In this work, for the sake of simplicity and uniformity, both gas and liquid concentrations are expressed in the same units—viz., lbs. per c.ft., time is in hours, and area in square feet, so that *the film transfer co-efficient may be defined as the number of pounds of solute transferred per hour per square foot of interface when the concentration difference across the film is 1 lb. of solute per cubic foot.*

Concentrations at the interface would be very difficult to measure and are in general not known, so that it is desirable, if possible, to obtain expressions from which these have been eliminated. This can be done very simply if the absorption is one to which Henry's Law is applicable.

Let k be the partition factor so that, since there is equilibrium at the interface,

$$L_i = k.G_i,$$

and if G_1 represent the concentration in gas that would be in equilibrium with the main body of the liquid

$$L_1 = k.G_1.$$

Then

$$\frac{1}{A} \cdot \frac{dW}{dt} = k_g (G_g - G_i) = k_1 (L_i - L_1) = k.k_1 (G_i - G_1)$$

so that

$$\frac{1}{k_g} \cdot \frac{1}{A} \cdot \frac{dW}{dt} = G_g - G_i$$

and

$$\frac{1}{k.k_1} \cdot \frac{1}{A} \cdot \frac{dW}{dt} = G_i - G_1.$$

Adding these we have

$$\left(\frac{1}{k_g} + \frac{1}{k.k_1}\right) \cdot \frac{1}{A} \cdot \frac{dW}{dt} = G_g - G_1$$

or

$$\frac{1}{A} \cdot \frac{dW}{dt} = \frac{1}{\frac{1}{k_g} + \frac{1}{k.k_1}} (G_g - G_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

That is, the rate of transfer is proportional to the difference in concentration between the gas and gas that would be in equilibrium with the liquid. This difference may, by analogy with fluid flow, be termed the "concentration head." The above equation may be written:

$$\frac{1}{A} \cdot \frac{dW}{dt} = K_g . (G_g - G_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where K_g is the "over-all transfer co-efficient," and is given by

$$\frac{1}{K_g} = \frac{1}{k_g} + \frac{1}{k.k_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Thus the over-all transfer co-efficient can be calculated from the individual film co-efficients and the partition factor when Henry's Law applies. K_g is the rate of absorption per unit area of interface per unit difference of concentration between the main gas phase and gas in equilibrium with the main liquid phase. In the above expressions concentrations in both phases are in terms of the equivalent concentrations in gas. They might equally well have been expressed as concentrations in liquid. For

[2] J.S.C.I., 1885, **4**, 639.
[3] J.I.E.C., 1916, **8**, 825.
[4] J.I.E.C., 1922, **14**, 185.
[5] J.S.C.I., 1920, **39**, 236T.
[6] Chem. and Met. Eng., 1920, **23**, 1115.
[7] Chem. and Met. Eng., 1923, **29**, 146.

if L_g represent the concentration in liquid in equilibrium with the gas concentration G_g.

$$L_g = k\,G_g$$
$$\text{also } L_1 = k.G_1$$

Substituting these in equation (3) we have

$$\frac{1}{A}\cdot\frac{dW}{dt} = K_g\,.\,\frac{1}{k}\,(L_g - L_1)$$

If K_1 represent the over-all transfer co-efficient per unit difference of concentration between the main liquid phase and liquid in equilibrium with the main gas phase

$$\frac{1}{A}\cdot\frac{dW}{dt} = K_1\,.\,(L_g - L_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$\text{and } \frac{1}{K_1} = \frac{k}{K_g} = \frac{k}{k_g} + \frac{1}{k_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

The reciprocals of the transfer co-efficients represent the resistance to transfer. Thus if R signifies the total resistance and r the resistance of one film

$$R = r_g + r_1$$

while $r_g = \frac{1}{k_g}$ and $r_1 = \frac{1}{k.k_1}$ in terms of gas concentration,

$r_g = \frac{k}{k_g}$ and $r_1 = \frac{1}{k_1}$ in terms of liquid concentration.

The ratio of the film resistance is therefore given by

$$\frac{r_g}{r_1} = \frac{k.k_1}{k_g} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

It is obvious from the above that in order to determine the rate of transfer in a given system it is necessary to consider the magnitude of both resistances, but in certain special cases the problem is much simplified because one resistance is so much greater than the other that the latter may be neglected without any appreciable loss of accuracy. Thus if the gas is extremely soluble, so that k is very much greater than any likely value of the ratio $\frac{k_g}{k_1}$, the value of $\frac{1}{k_g}$ is so great compared with $\frac{1}{k.k_1}$ that the gas film resistance alone need be considered. On the other hand, when the solubility is very low, the resistance of the gas film is by comparison so small that the rate of absorption is entirely controlled by the liquid film resistance.

Examples of the first type, in which the gas film resistance controls the absorption, are the absorption of ammonia by water or acid, hydrogen chloride by water, sulphur dioxide by alkali. The second type, in which the liquid film controls, is exemplified by the absorption of oxygen or carbon dioxide in water. In the case of such an absorption as sulphur dioxide in water, in which the solubility is neither very high nor very low, the resistance of both films must be taken into account, so that any factors that affect either the gaseous or the liquid phase may influence the rate of absorption. In any such intermediate case there may be special conditions that tend to diminish disproportionately the resistance of one film, so that it may become permissible to simplify by assuming single film control. For example, in the absorption of sulphur dioxide by water if, by inducing a high degree of turbulence in the gas by means of high velocity, baffling, &c., the stagnant gas film is kept so thin that diffusion readily occurs through it and k_g is very high, practically the whole of the change in concentration occurs across the liquid film and the problem can be treated as one of liquid film diffusion alone. On the other hand, when the gas phase is comparatively undisturbed the resistance of the gas film is high and may become nearly equal to that of the liquid film.

Factors Affecting the Gas Film Co-efficient.—Since the film co-efficient represents the rate at which the solute diffuses across the film, it is dependent on the thickness of the film and on the specific diffusivity of the solute through the fluid medium. Anything that affects either of these, therefore, will have a corresponding influence on the film co-efficient.

Film Thickness.—The thickness of the gas film depends on the particular type of apparatus or plant, on the viscosity of the gas, and on the amount of turbulence therein, a high degree of turbulence tending to carry convection nearer to the interface and thus diminish the film thickness. In a given piece of apparatus the internal turbulence of the fluid increases with its velocity, so that the thickness of the film may be expressed as a function of the fluid velocity and its viscosity. This relation has been investigated by many workers, and in general it is found that it can be represented very closely by a power law, so that if x is the thickness of the film, z is the viscosity of the the gas, and v its mass velocity—*i.e.*, the mass flowing per square foot of cross-section of the stream per minute—then

$$x = b\,.\,\left(\frac{z}{v}\right)^n$$

where "b" is a constant for the particular apparatus. When the general flow is turbulent the value of "n" usually lies between 0·5 and 0·8, while for streamline flow it has about half this value. In practical gas washers measures are usually taken to ensure turbulent flow.

Diffusivity.—The actual diffusivity or co-efficient of diffusion of the solute through the carrier gas is a matter of some complexity and the data on the subject are rather meagre. Arnold[8] has shown that the co-efficient can be calculated from the equation

$$D = \frac{0{\cdot}00837\sqrt{\frac{1}{M_A} + \frac{1}{M_B}}}{(V_A^{\frac{1}{3}} + V_B^{\frac{1}{3}})^2}\cdot\frac{T^{2{\cdot}5}}{T + C}\ \text{cm.}^2\ \text{per sec.} \quad . \quad . \quad . \quad (8)$$

where D is the co-efficient of diffusion at atmospheric pressure.

M_A and M_B are the molecular weights of the diffusing gases,

V_A and V_B are the molecular volumes of these gases in the liquid form at their boiling points,

T is the absolute temperature in °K,

and C is Sutherland's constant for the mixture.

The co-efficient is independent of the actual proportions of the two gases, but is inversely proportional to the total gas pressure. The effect of temperature is not simple, as will be seen from the above expression, but in general it may be said that D varies as a power of T, the index of which is between 1·75 and 2·0. For the rapid calculation of transfer co-efficients in practice the above expression is too cumbrous and the data required are not readily available. In place of it a rough practical rule is that diffusivity varies approximately inversely as the square roots of the molecular weights of the diffusing gases. It should be noted, however, that this, which is similar to Graham's law of effusion, is only accurate to within about 35% for diffusion phenomena. Combining the effects of diffusivity and film thickness into one expression the gas film transfer co-efficient is given by

$$k_g = \frac{aD}{P}\left(\frac{v}{z}\right)^n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

or approximately by

$$k_g = \frac{a'}{P\,.\,M_A^{\frac{1}{3}}\,M_B^{\frac{1}{3}}}\left(\frac{v}{z}\right)^n \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9A)$$

where a and a' are constants for the particular apparatus, D is the diffusivity of the solute through the gas at atmospheric pressure and P is the total gas pressure. Densities may be substituted for molecular weights in equation (9A), which then becomes applicable to complex gas mixtures.

In many commercial absorption operations the gas pressure is approximately atmospheric and varies so little that the effect of the total pressure P may be ignored. On the other hand, in those operations that are carried out at very high pressures the reduction of diffusivity by pressure alone is of great importance.

Influence of Temperature.—Haslam, Hershey, and Keen[9] found that at constant linear velocity k_g varies as $T^{-1{\cdot}4}$. Since in their work concentration is expressed in terms of partial pressure, and since they found that k_g varies as the 0·8 power of gas velocity, it follows that at constant *mass* velocity, k_g, in the units adopted here, should vary as $T^{0{\cdot}4}$—an effect too small to be easily measured or to be of importance over a limited temperature range. Hence, as a first approximation, it may be assumed that k_g is independent of temperature.

Liquid Film Co-efficient.—Much less is known of the factors affecting the liquid film. Moreover, it is particularly difficult to generalize for those types of plant in which the liquid flows in a layer over the surfaces of solid material, because the character and magnitude of the film depend very much on the nature and arrangement of the parts. It is fortunate, therefore, that the liquid film is usually of minor importance in technical absorptions, for, if possible, an absorbent is usually chosen in which the solute is highly soluble.

In many instances the co-efficient k_l appears to be inversely proportional to the viscosity of the liquid, and hence increases rapidly with rising temperature. Haslam, Hershey, and Keen[9] state that it is proportional to the fourth power of absolute temperature.

Published data for diffusivity through water and aqueous solutions show surprisingly little variation for different substances, so that as a first approximation the liquid film co-efficient may be regarded as independent of the nature of the solute.

The above conclusions regarding the effect of various conditions on the magnitude of the film co-efficients have been tested by small-scale investigations in the laboratory on rates of transfer in a counter-current apparatus, and are in general agreement with the results obtained. It was found necessary to carry out this fundamental work as part of

[8] Ind. Eng. Chem., 1930, **22**, 1091.
[9] Ind. Eng. Chem., 1924, **16**, 1224.

the general investigation of gas washers, because much of the previous work was contradictory and had been interpreted in a way inconsistent with the modern two-film theory. Before these experiments are described, however, a brief analysis of the counter-current washer problem will be made with the object of deriving the simple expressions which were used in interpreting the results and which have since proved of value in dealing with practical washers.

III. Rate of Absorption in a Counter-Current Washer.

The mathematical analysis of the rate of absorption in a counter-current washer, which may be either a packed tower or a spray tower or of the wetted wall type, was first made by Partington and Parker[10] for the special case where the solute is chemically fixed by the liquid instantaneously on absorption. The general case where the absorbable gas has a definite solubility in the liquid was treated by Donnan and Masson.[11] A form of nomenclature differing from that of these workers has been adopted below in order to make the analysis rather simpler, and the resulting expressions more convenient to apply.

It has been shown above that the rate of absorption of a soluble constituent at any point in a washer is proportional to the difference between the concentration in the gas and that concentration in gas that would be in equilibrium with the liquid at that point. In a counter-current washer, such as a tower scrubber, this difference, or "concentration head," varies continuously from point to point in the stream, although it may remain constant at any one point. In order to determine the rate of absorption for the whole scrubber, it is necessary to find a mean value for this concentration head. A simple expression for the concentration head can be deduced mathematically if it may be assumed that the partition factor is constant for the whole washer. This condition embraces not only the cases where Henry's Law applies, but also those in which the vapour pressure of the constituent over the solution is negligible, for then k is infinite. The latter condition holds, for example, when close chemical combination takes place, as in the absorption of ammonia by dilute sulphuric acid. In practice, this assumption of constant partition factor is usually not quite correct, for even if the absorption is entirely governed by Henry's Law, the temperature usually varies from point to point on account of the heat evolved by the solution of the constituent. The equalizing effects of radiation and the convection of heat by the moving fluids, however, tend to minimize this temperature variation. In general, even where Henry's Law is not obeyed, it is often sufficiently exact to take a mean value of the partition factor and apply it to the whole washer.

In the following analysis it is assumed that the temperature remains approximately constant throughout the washer, that Henry's Law applies, that the rates of flow of gas and liquid are constant, and that conditions in the washer do not vary, so that at any fixed point in the washer the concentrations of liquid and gas do not change; also that the packing, if any, is uniformly distributed and that the distribution of liquid is similar at all levels. It is also assumed that the volume of gas does not change in passing through the tower. This is usually approximately true, for the increase in volume due to the reduction in pressure in passing to the outlet end of the washer is to some extent balanced by the reduction in volume due to the absorption of the solute.

Starting from these assumptions it is demonstrated that the rate of absorption in a counter-current washer is equal to the product of the co-efficient of transfer, the effective area of interface between gas and liquid and the logarithmic mean of the concentration heads at the two ends of the washer provided it may be assumed that Henry's Law is applicable. The equation expressing this relation is

$$W = K_g A \frac{\theta_0 - \theta_1}{\log_e \frac{\theta_0}{\theta_1}} = K_g A \theta_m \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (16)$$

where

W = the weight absorbed in the whole washer per hour
K_g = the transfer coefficient = lbs. absorbed per hour per sq. ft. of interface for a gas concentration difference between gas and liquid of 1 lb per c.ft. of gas.
A = the total area of gas-liquor interface.
θ_0 and θ_1 = the concentration heads in lbs. per c.ft. at the bottom and top of the tower respectively.
θ_m = the logarithmic mean of θ_0 and θ_1.

Characteristic Formula for a Counter-Current Washer.—As examples of problems relating to the design and performance of tower scrubbers or other counter-current washers mention may be made of the determination of the size of plant necessary for the removal of a given proportion of solute from a given volume of gas, or of the proportion removed by a given scrubber under stated conditions. Such problems can be solved by means of the above expression, but it will be found much more convenient and direct to apply the formula (17) which expresses the above relation in another way.

$$\frac{K_g A}{V} = \frac{qk}{qk - 1} \log_e \left(\frac{qk - 1 + S}{qkS} \right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

When $qk = 1$, equation (17) is indeterminate, but the following may be substituted:

$$\frac{K_g A}{V} = \frac{1 - S}{S} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (17A)$$

When the feed liquid already contains some of the constituent to be absorbed it can be shown that equations (17) and (17A) still apply if S' be written for S where S' represents the proportion unabsorbed, not of the total concentration in the entering gas, but of that part of the concentration which is in excess of that in equilibrium with the feed liquor, so that

$$G_1 - \frac{L_1}{k} = S' \left(G_0 - \frac{L_1}{k} \right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (18)$$

Equations (17) and (17A) are the characteristic equations for a counter-current washer. They express the relation between the rates of flow of gas and liquid, the dimensions of the tower, the transfer co-efficient, and the slip, enabling any one of these to be calculated if the others are known.

It should be noted that actual concentrations do not appear in the final equations. It follows from this that the proportion of solute removed from gas in a given tower is independent of the initial concentration, provided that the partition factor does not vary therewith.

These expressions can be used for calculating the performance of a given plant, or for the design of a tower-scrubber, if the transfer co-efficient and the active surface per unit volume of packing are known. It is sometimes difficult to determine these separately, but the product $K_g a'$, which is the transfer co-efficient per unit volume of packed space, can usually be found experimentally for any particular packing. The equations have also proved useful in interpreting the small-scale experiments described in a later section.

Minimum Slip.—It is obvious that the slip decreases progressively as the volume of washing liquid is increased, but it follows from equation (17) that there is a minimum below which the slip cannot be reduced by thus merely increasing the flow ratio, for if q (and consequently qk) be put equal to infinity, the equation reduces to

$$\frac{K_g A}{V} = \log_e \frac{1}{S} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19)$$

i.e., the minimum possible slip is given by

$$\log_e S = -\frac{K_g A}{V} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (19A)$$

Equation (19) also applies when q is finite but k is infinite—that is, when the solute enters instantaneously into chemical combination with the liquid so that the resulting solution exerts no vapour pressure of this constituent.

Graphical Solution.—In practice equation (17) may sometimes prove difficult to solve, particularly if it be desired to determine the volume of feed liquor to ensure a given performance. For this purpose the equation has to be solved for q, which appears both inside and outside the logarithm. To overcome this difficulty and to simplify the work of calculation generally, the reference diagram in fig. 1 has been prepared, by the use of which it is possible to solve in a few seconds any problem to which the equation is applicable.

As an example, suppose a certain tower allows a slip of 5% when 80 gallons of washing liquid are used per 10,000 c.ft. of gas, the value of k being 856. How much liquid must be used if the slip is to be reduced to 1% of the concentration in the entering gas:

$$k = \frac{80 \text{ gallons}}{10{,}000 \text{ c.ft.}} = \frac{12{\cdot}83 \text{ c.ft.}}{10{,}000 \text{ c.ft.}} = 0{\cdot}001283$$

$$qk = 856 \times 0{\cdot}001283 = 1{\cdot}10.$$

The curve for $qk = 1{\cdot}10$ cuts the vertical for S = 5% at the point where $\frac{K_g A}{V} = 11{\cdot}0$. Since the scrubber has not been altered in any way, and the volume of gas passing per hour is unchanged, the value of $\frac{K_g A}{V}$ is the same for the new conditions. The point $\frac{K_g A}{V} = 11$, S = 1% lies between the lines $qk = 1{\cdot}4$ and $qk = 1{\cdot}6$ and by interpolation qk is estimated at 1·46. The partition factor is unaltered, so that the flow ratio required is $80 \times \frac{1{\cdot}46}{1{\cdot}1} = 106$ gallons per 10,000 c.ft.

IV. Laboratory Experiments on Rates of Absorption.

An extended series of laboratory experiments on rates of absorption on the walls of a small glass tube was de-

[10] J.S.C.I., 1919, **38**, 75T.
[11] J.S.C.I., 1920, **39**, 236T.

scribed. Transfer co-efficients at varying velocities of gas and liquid were determined for the absorption of ammonia from air and from coal gas by water and by dilute sulphuric acid; of sulphur dioxide by dilute sulphuric acid and by dilute caustic soda; and of hydrogen sulphide by water and by dilute caustic soda. The results were correlated by means of the above theoretical expressions and provided a very good experimental verification of them.

V. Distribution of Liquid in Tower Scrubbers.

The data on transfer co-efficients discussed above should be applicable to problems relating to gas washers, particularly where board filling or small packing material is used, since the size of the experimental tube was of the same order as the individual spaces between the material in these instances.

An important practical difficulty in making the application, however, is that of estimating the area of interface at which absorption is taking place; for, although the whole of the surfaces of the packing may be presented to the gas stream, only a part of it is covered with a continuously flowing layer of liquid. The proportion of the surface that is so covered, and not merely wetted, depends on the rate at which liquor is fed to the washer; for it is very difficult, particularly with small rates of flow, to ensure an even distribution of the liquid over the whole upper surface of the packing, and it is impossible to constrain this liquid to spread itself in a perfectly even layer over the whole of the packing in the tower. The ratio of the actual active wetted surface to the maximum surface that can be actively wetted by indefinitely increasing the liquor rate may be represented by a distribution factor Δ so that if a' is the area of packing surface per unit volume the available area for absorption is $\Delta.a'$ and the transfer co-efficient per unit volume of packed space is $\Delta.K_g a'$.

Kowalke, Hougen, and Watson[12] have determined values of Δ for different forms of packing at various liquor rates, and showed that the distribution factor decreases rapidly as the rate of liquor flow falls off. In a short tower (4 ft. high) packed with boards on edge they found that the rate of water flow required to make $\Delta = 0{\cdot}9$ was 36 gallons per sq. ft. of cross-section per hour. Whether such a high distribution factor would be obtained with a full-size tower is doubtful, for it has often been stated that in packed towers used as washer-coolers the rates of absorption and of heat transfer begin to fall off when the liquor rate falls below 120 gallons per sq. ft. per hour.[13] Such high liquor rates are quite impracticable in counter-current ammonia towers under gas-works conditions where the volume of the liquor has to be kept down to a minimum. Thus for the washing of 3,000,000 c.ft. of gas per day, using 5 gallons of water per 10,000 c.ft. of gas, a tower only 1 ft. 6 in. in diameter would be required if the rate of 36 gallons per hour were to be maintained. Such a tower would be impracticable on account of the great height necessary and the pressure head required to force the gas through it. Towers of much greater cross-section are in general use, the dimensions of which are more nearly in accord with a rule due to T. Glover,[14] who recommended a flow equivalent to 8·7 gallons per hour per sq. ft. of cross-section for a board-filled tower, the basis of the rule being that he found by observation that the liquor dripped evenly from the lower edges of the boards in a tower fed with water at this rate. It does not necessarily follow that the whole or any large part of the wetted surfaces is in an active condition—*i.e.*, covered with a flowing and constantly changing film of liquid. The value of Δ for these conditions is probably very low indeed, judging from the actual performance of such towers. It may be supposed, for example, that the liquor flows down in the tower in narrow streams rather than as a uniform film.

This difficulty of obtaining satisfactory distribution limits the effective use of tower-scrubbers as counter-current washers to those operations in which a large quantity of liquid is used in relation to the volume of gas washed—that is, to the removal of gases of low solubility or to operations where the volume of liquid is unimportant, so that a large excess may be employed without disadvantage. The practice of recirculating the liquor over and over the tower may improve distribution but only at the expense of a total sacrifice of the counter-current principle. The multi-stage washer is a very effective compromise between these two methods of working.

Further research on the design of counter-current washing plant, leading to the improvement of liquor distribution at low rates of flow, should be of great value in that a considerable reduction in size and cost of plant should result, accompanied by an increase in washing efficiency. Work of this character is now in hand. In a following paper* one of us describes application of these general principles of multi-stage washers.

We wish to thank the Directors of the Gas Light and Coke Company, in whose Fulham laboratories the experiments described have been conducted, for permission to publish this paper.

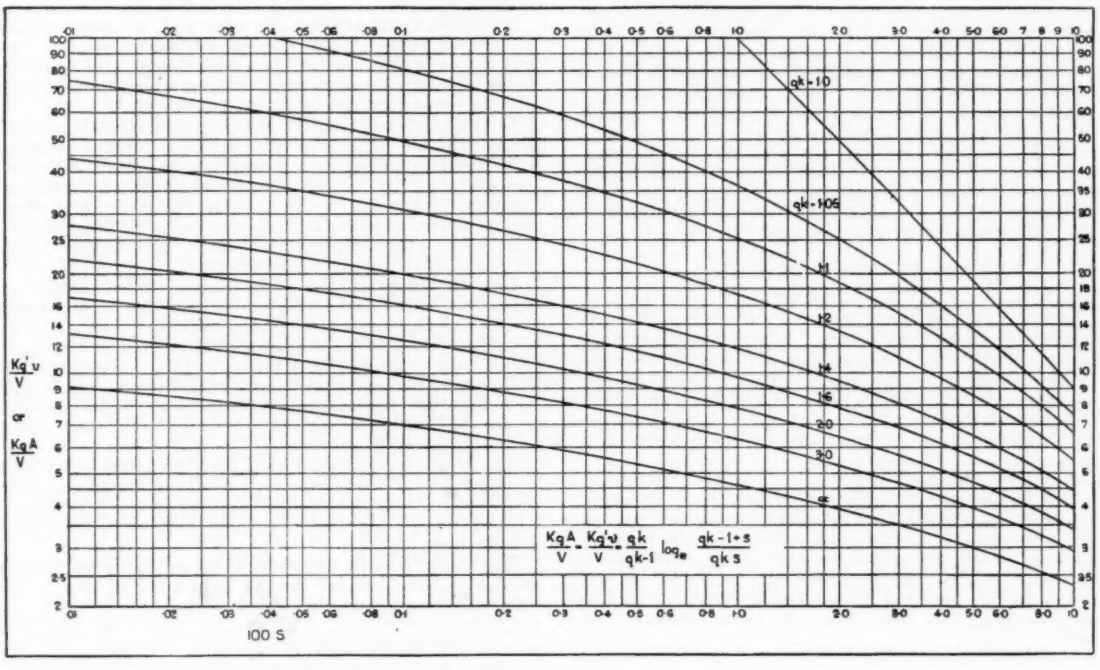


FIG. 1.—CURVES CORRELATING $\frac{K_G A}{V}$ WITH PERCENTAGE SLIP (100 S) FOR DIFFERENT VALUES OF qk.

[12] Chem. and Met. Eng., 1925, **32**, 506.
[13] Clisham, Am. G. J., 1923, **118**, 517.
[14] "Gas Journal," 1914, **125**, 892. * To be published later.

Gas in the Development of the City*

By A. W. Smith, General Manager and Secretary to the Birmingham Gas Department.

In the design of houses, the architect's last thought is the provision of proper accommodation for a gas meter or cooker, or other apparatus.

It is no exaggeration to say that the development of any city in these days depends to a very considerable extent upon its gas undertaking. It is invariably found that where there is an out-of-date gas company, there is very little progress and activity in the community it pretends to serve. But where the undertaking is alive and progressive, its activities are reflected in an enlightened and progressive development throughout its area.

When we have in Birmingham decided to adventure in the laying of gas mains to an undeveloped district, the fact that the amenities which gas can give were available has resulted in rapid development of that particular area.

The post-war housing problem has been more wholeheartedly attacked in Birmingham than in any other provincial city, and the new housing estates have been the cause of an immense capital outlay on the part of the Gas Department.

While not defending the type of "town planning" indulged in prior to the war, you will readily realize how much more profitable it was for my Department to lay mains in new roads pre-war, when such roads usually ran perfectly straight, and were flanked on either side by a continuous row of houses, each with a frontage of perhaps 12 ft., and set back merely 8 or 10 ft. from the public footpath.

Contrast this with the lay-out of one of the new housing estates, with its crescents, its closes, and its boulevards. Imagine our Distributing Engineer having to lay his cast-iron mains along these pleasing curves, and the difference in capital outlay per consumer is at once obvious.

The Lighting of Birmingham.

In 1870 there were only 3865 street lamps in the City of Birmingham; to-day we have many miles of streets and roads lighted by 26,000 gas lamps. I ought perhaps here to attempt to remove the impression which seemingly exists in the minds of many people in this city that the Gas Undertaking is responsible for the *adequacy* or otherwise of the street lighting. This is not so. Gas can give whatever illumination is needed, depending upon the size of the unit adopted.

It is very certain that nothing has done so much to reduce crime in our streets as improved lighting. Progress has done much to reduce the criminal population in our city, but if we were plunged into darkness even for one night, it is extremely probable that robbery or crimes with violence would occur. My Department is proud of the fact that such a "blot out" has never occurred in the long number of years that gas has been used as an illuminant.

It may be interesting to mention a fact that is perhaps better known to strangers than to our own citizens—namely, that Victoria Square, which is lighted by high-pressure gas, has been since 1911, and still is, the best lighted area in Europe. This installation gives a higher illumination result than Specification A. of the British Standards Institution.

We often hear unthinking people—and sometimes those who should know better—talk about the possibility of electricity supplanting the Gas Industry; in fact, quite recently a prominent gentleman who has been given an important position in the electrical industry used, in his impetuosity, a phrase which I expect he now regrets—"that he was going to give the 'knock out blow' to gas."

In view of such statements, it will perhaps be interesting to you to know that the 5 million c.ft. of gas sent out in one hour each Sunday by the Birmingham Gas Department would, if replaced by electricity, expressed in terms of heat energy, require more than seven generating stations of the present size of the Hams Hall Power Station.

The relative positions of the two industries can perhaps be better appreciated if I give you the figures relating to the Gas Light and Coke Company. Their maximum hourly output of gas was on Sunday, Feb. 19, 1933, and reached the stupendous figure of 18,489,000 c.ft. during the cooking hour.

To send out this quantity of thermal energy in one hour would require a power station twenty times the size of the present new Battersea Power Station, or 11½ times the size of the largest electrical generating station in their area—namely, Barking.

This position is seldom appreciated by the general public.

When the electrical industry has discovered a storage system equal to the gasholder they may begin to talk about supplanting the Gas Industry.

The Traffic Problem.

If the thermal energy conveyed by a pipeline had to be dealt with by solid fuel, there would be such a stream of traffic as would paralyze any traffic control committee.

For instance, in London two 48-in. gas mains run from the Beckton Gas-Works of the Gas Light and Coke Company to the West End of London. It is estimated that to deliver this same thermal energy in the form of solid fuel would necessitate a continuous stream of coal wagons throughout the 24 hours.

In our own city, similar progress is going on unnoticed.

No fewer than 170,000 gas fires and 280,000 gas cookers in homes; many thousands of muffles, furnaces, boilers, and other appliances in factories have heat supplied to them silently, cleanly, and without the slightest obstruction or inconvenience to other dwellers.

It has been stated that Birmingham owes the existence of its jewellery trade to the fact that we were among the very earliest towns in the country to afford a public gas supply—gas, of course, being used extensively in the jewellery trade for muffles, soldering irons, &c. The big development in the use of gas for industrial purposes, however, is of much more recent date, and was given a tremendous fillip during the great war.

Our service to industry is a highly important side of our activities. We have developed over 23 or 24 years an Industrial Research Laboratory which is constantly aiding manufacturers in the solution of their heat-treatment problems and in many other ways; in fact, so well known has this service become that we are called upon very frequently to help other towns, and manufacturers in other districts in the utilization of gas for their carburization and other heat-treatment problems.

Gas now plays its part as a fuel in the majority of heat-treatment processes connected with the multifarious trades of the city, from the small blow pipe in the jewellery trade to the large-scale heat-treatment furnaces in the automobile works.

The replacement by gas of many furnaces previously solid fuel fired has led to the lightening of heavy labour, generally cleaner conditions of workshops, healthier conditions for workpeople, and at the same time has assisted greatly in speeding up production. There is also greater accuracy of working and improved quality of products.

All these advantages have undoubtedly had a great bearing on the manufacturing capacity of the city.

Our load for industrial purposes alone has increased to practically one-third of our total output, and at our heat-treatment shops at Windsor Street Works we carry out a large amount of work which manufacturers are unable to perform themselves.

In one of the factories in Birmingham we have installed large batteries of gas furnaces for heat-treatment, and the consumption of gas by this one firm alone will, it is anticipated, approach 180 million c.ft. per annum.

Future of the Gas Industry.

The future development of the Gas Industry is, in my view, likely to follow on somewhat similar lines—but more practical and economic—to the National Grid Scheme in Electricity. There is no difficulty in the provision of gas to "satellite" towns or estates; it is a type of development which is favourable to gas supply undertakings. Our mains are being used very little during five or six hours of the night. During these hours gas could be supplied to holders near a satellite town to cope with the demands of a normal day load.

The fact that gas can be stored is a very great point in its favour, as is also the fact that it can be transported easily from place to place, although in Great Britain the provision of long distance mains is retarded by legal diffi-

* From a lecture at Birmingham University on Jan. 30, 1934.

culties, restricted areas of supply, local authorities' objections to the opening up of their roads without the obligation to supply, cost of wayleaves, &c.

There is no unsurmountable technical or engineering difficulty in the establishment of a "Gas Grid," although centralized production of gas would probably be uneconomic. I have always held that instead of appointing Electricity Commissioners, the Government would have acted more wisely if they had appointed experts as Fuel Commissioners to survey the whole question of fuel, and to harness scientifically the whole of our national resources in this field of activity.

I often wonder what would have been the position to-day in the Midland area if Mr. Joseph Chamberlain had not persuaded the Birmingham Corporation to buy up the two large Gas Companies which were operating here prior to 1875. The Companies were at the time considering an amalgamation, which would doubtless have taken place in the absence of municipal opposition.

The Birmingham and Staffordshire Gas Company at that time supplied not only Birmingham, but Oldbury, Smethwick, West Bromwich, Walsall, Tipton, Wednesbury, Darlaston, and many other Black Country towns; and there is little doubt that had the amalgamation been allowed to take place, we should have seen to-day a public utility undertaking operating over the whole of the Midland area, instead of its being split up into units, each with its statutory area of supply, and its variation in gas prices and gas services.

Although Birmingham as a city has benefited very considerably by the purchase of the Undertaking, it is doubtful whether the community as a whole would not have been better off if the Companies had been left to develop and extend their public utility activities.

"The Practice of Engineering Estimating"*

Reviewed by T. Campbell Finlayson, M.Sc., M.I.Chem.E.

In this book Mr. Percy H. Miller sets out to explain by what steps the drawings of a machine, a plant, or a factory can be converted into an accurate estimated cost. He stresses that guesswork, however intelligent, is no substitute for fact, and that therefore engineering estimating should be considered as a science rather than an art.

In his preface the author suggests that estimating accuracy depends upon three factors—years of experience, the making of pertinent records, and a knowledge of markets. In his view the first and second factors can in a large measure be handed on, while the last usually changes but slowly and may be used as a constant whose value can be altered with changing conditions. He further expresses the hope that his book will enable not only the professional estimator, but the busy executive, to prepare estimates either approximate or of a high degree of detailed accuracy with a minimum of effort.

Mr. Miller has certainly produced an essentially practical volume on this subject. While giving due attention to principles, he is not afraid to support his ideas with facts. The book is packed from end to end with phrases which give the science of estimating its own axioms.

The author deals with his subject in two sections—first, civil engineering requirements of industrial works, and, secondly, detailed estimating in connection with mechanical engineering. The section on civil engineering relates to the building of the factory and covers such problems as roads, excavations, foundations, and building construction. Detailed consideration is given to cost of work of different trades, such as bricklayers, carpenters, slaters, plumbers, and so on.

Some impression of the detailed information contained in this book may be gathered from a glance at the information on building costs. Mr. Miller states that the average cost of steel-framed buildings in one storey and covered with galvanized corrugated iron sheeting is 3½d. to 4d. per c.ft. If covered with asbestos sheeting the cost will be 4½d. to 5d. Wood-framed buildings in place of steel-framed buildings, but otherwise similar, would be ½d. to ¾d. per c.ft. cheaper. And so on to two-storied buildings and brick buildings. In the sections relating to tradesmen's work equally definite figures are given, such as, for example, "a painter will distemper, where ladders are not required, at the rate of 5 super yards per hour, and where ladder work is necessitated at the rate of 3 super yards."

The normal proportions of labour to materials are for a carpenter 1:2 and for a joiner 2:1. A paperhanger should paste and hang at the rate of 100 super feet area covered in 2 to 2½ hours.

Such statements as these make it comparatively simple to prepare an estimate. But it is somewhat difficult to see how one can determine whether the result is a close approximation to the buying price. One can but take the author's word for the accuracy of his axioms. The precision with which the figures are given inspires confidence, but even so it is suggested that in the next edition it might be an advantage to indicate the author's connection with the practice of estimating.

The second section of the book discusses the preparation of detailed estimates in connection with mechanical engineering. To begin with, the meaning of administration charges is defined and the assessment of these charges in estimates is discussed. The make-up of an estimate is next discussed, and then the author proceeds to give detailed information on the estimating of mechanical equipment made of cast iron, steel, non-ferrous metals, and so on.

Consideration is given to the costs of the various processes within the machine shop, such as turning, planing, milling, welding. Finally, the author deals with plant erection at site.

In his preface Mr. Miller refers to some books on this subject of estimating which remain too vague and diffuse to help one in solving every-day practical problems.

Such a charge cannot be levelled against the present volume. As has already been indicated, the author is not afraid to give figures, and while it may be that certain of the items may be varied by individual estimators, yet it will not be disputed that he has given a mass of basic data which are of considerable value.

To many readers this book will well repay its modest published price.

* "The Practice of Engineering Estimating," by Percy H. Miller. From the Oxford University Press, London, Humphrey Milford, Publisher to the University; pp. 192. Price, 12s. 6d. net.

Legal Intelligence.

Patent Action.

Mitchell, F. G., *v.* West's Gas Improvement Company, Ltd.

An action against West's Gas Improvement Company, Ltd., of Manchester, in which Mr. Fredk. Gilbert Mitchell, of Romford, asked for an injunction to restrain the Company from infringing his letters patent 228,956, of 1923, was heard by Mr. Justice Bennett in the Chancery Division. Mr. Mitchell also asked for damages and for delivery up of certain apparatus which he alleged was infringement.

It was stated that the patent relates to an invention called improvements in or relating to apparatus for tipping and discharging railway wagons, and the plaintiff complained that the defendant Company sold some of the infringing apparatus to the Southport Corporation for their gas-works and that they also had sold it to the Gas Light and Coke Company. Plaintiff is the Managing Director of the Mitchell Conveyor and Transporter Company, Ltd., manufacturers of apparatus for unloading coal and other materials, and he was the inventor of the mechanism.

The defendant Company, denying the infringement, asserted that the patent was not valid because of lack of novelty and prior publication and common knowledge.

The action was dismissed, the judge holding that, although the patent was valid, there had been no infringement by the defendant Company. The real contest was whether the apparatus sold by defendants infringed the patent, and it was admitted by plantiff that, if words used in the description of his apparatus limited monopoly claimed for the invention, the defendants could not be said to have infringed it. On the construction of the specification, His Lordship thought the words were of limitation.

Theory of Small Gas Governors*

By W. E. Benton, M.Sc., Chief Chemist, Cannon Iron Foundries, Ltd.

The purpose of a small governor is to control either the rate of flow of gas through an appliance or the applied gas pressure. Two fundamental principles form the basis of all small governors:

(1) The power required for operating the control must be supplied by the gas itself.
(2) The device should be so made that any disturbance in the mean conditions immediately gives rise to a resisting force tending to restore the conditions to normal.

In addition to these two basic principles, which are common to other mechanical devices, gas governors also make use of two principles which refer particularly to gas, the medium which they seek to control:

(1) That a constant weight acting on a diaphragm, open on the weighted side to the atmosphere, will exert a constant pressure in excess of atmospheric.
(2) That under a constant pressure difference a given orifice will pass a constant flow of gas, provided that the density does not vary.

The application of the first principle enables one to make a constant pressure governor, the application of the second a constant volume governor. It will be seen that whereas governors of the first class must have access to the external air, those of the second type can be hermetically sealed, since the constant pressure difference can be obtained without reference to the atmosphere. This constitutes the only distinguishing difference between the external features of these two types of governor. Internally, although the method of working is different, there is no feature which is peculiar to either type.

Constant Pressure Governor.

Fig. 1 shows a simple instrument of the constant pressure type. A leather diaphragm AB supports a pan CD, which is loaded with a suitable weight E and the attached valve stem F and valve G. When no gas pressure is applied the pressures on the two sides of the diaphragm are the same, and equal to atmospheric pressure, P_o. The valve will therefore hang down in its lowest position, leaving a clear gas-way through the apparatus. Now if the total mass of the diaphragm, pan, weights, valve-stem, and valve be M, and the gravitational constant be g, a total weight or downward force of Mg poundals is supported by the diaphragm. If a gas pressure P_i be applied at the inlet, gas will flow unimpeded through the apparatus unless the total lifting force on the diaphragm against the atmospheric pressure exceed Mg. The lifting force will be the product of the pressure difference $(P_i - P_o)$ and the equivalent area A. The diaphragm is flexible, and the combination of pan and diaphragm will act as a piston of area less than the diaphragm AB, but greater than the pan CD.

When A $(P_i - P_o)$ exceeds Mg, the diaphragm will rise, lifting the valve until it causes such a hindrance to the passage of gas that the reduced pressure below the diaphragm is only just sufficient to prevent the valve from falling. In this position of equilibrium the upward forces on the diaphragm exactly compensate the downward forces due to weight, and the valve opening is maintained at the amount sufficient to maintain the pressure difference $(P_2 - P_o)$. The extent of the valve opening will of course depend on the consumption.

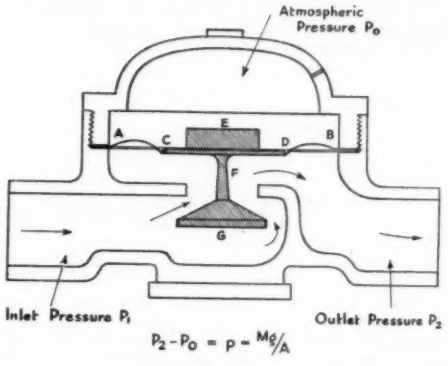


Fig. 1.

For convenience we will write $p_1 = P_i - P_o$
$p = P_2 - P_o$
whence $P_i - P_2 = p_1 - p$
Hence in this ideal case $pA = Mg$

$$p = \frac{Mg}{A}$$

It is useful to remember that 1 in. of water column is equivalent in pressure to about ½ oz. per sq. in. Therefore a small governor having a total valve and diaphragm weight of 3 oz., employing a diaphragm of equivalent area 3 sq. in., would maintain an outlet pressure of 2 in. of water column.

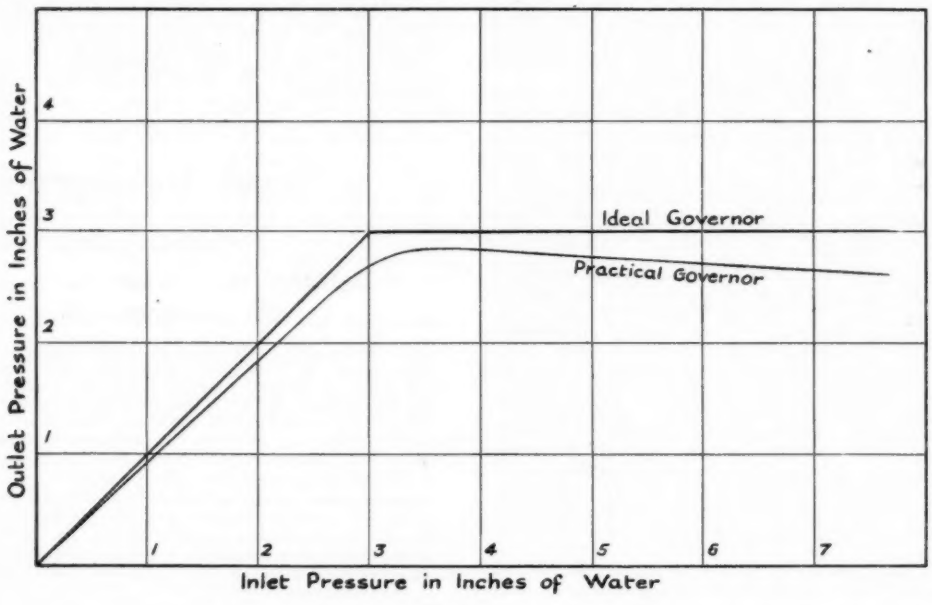


FIG. 2.

Error Due to Valve.

In fig. 2 are shown two curves, one representing the behaviour of an ideal constant-pressure governor, and the other the actual behaviour of a good type at present widely used. In the ideal case the outlet pressure is exactly equal to the applied pressure until the critical pressure is reached, when the outlet pressure becomes constant. In practice

* From a paper before the London and Southern District Junior Gas Association, Jan. 26, 1934.

governors may exhibit a slight resistance, evident in an initial slope less than 45°, and a steady governed pressure may not be maintained. In the graph shown the initial slope is very close to 45°, which indicates very low resistance, but after attaining a maximum the outlet-pressure slowly falls as the applied pressure is further increased. This can only be explained by the existence of some additional force tending to lift the valve and depending directly on the inlet pressure. A glance at our diagram will show that this additional lifting force must be due to (1) the difference of pressure between the surfaces of the valve itself, and (2) the small area of the valve-stem itself where the pressure difference is $(P_1 - P_0)$, since the valve stem allows of direct transmission of force between the high pressure P_1 and the atmosphere P_0.

Consider a simple form of governor (fig. 3) in which a plane circular valve opposes a plane valve-seating. Let r_1, r_2, and r_3 be the respective radii of the valve stem, the central valve aperture, and the valve itself, and x the

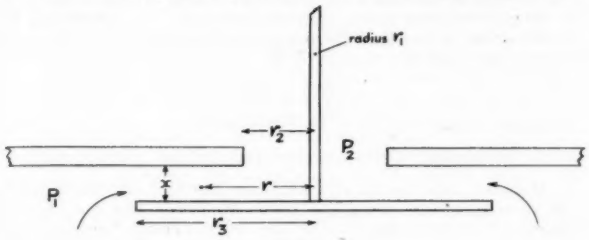


Fig. 3.

height of the parallel space between the valve and valve-seating. The total downward forces are as before, Mg, and the total upward force is made up of three parts:

(1) The direct thrust on the valve stem.
(2) The force due to the difference of pressure between the two sides of the valve over the space of the central opening.
(3) The force due to the varying difference of pressure between the two sides of the valve over the "covered" space from r_3 to r_2.

Of these the first is clearly $(P_1 - P_0)\ \pi r_1^2$. If we assume that the central opening is sufficiently large to offer a negligible resistance, then the pressure in the opening will be P_2 to a very close approximation, and the second term will be $(\pi r_2^2 - \pi r_1^2)(P_1 - P_2)$. The third term will be more difficult to assess. The constriction produced by the partial closure of the valve causes the gas to accelerate from a state of relatively slow movement at the inlet to a high velocity as it enters the constriction. Now the area of the constriction narrows steadily from $2\pi r_3 x$ at the entrance to $2\pi r_2 x$ at the central opening. The velocity will therefore rise steadily as the gas traverses the constriction, and, by a well-known law of hydrodynamics, the pressure will correspondingly fall. From the gas inlet to the outlet the pressure is at first steady at P_1, drops suddenly at the entrance to the constriction to a value rather greater than P_2, and then falls uniformly through the constriction to P_2 in the central opening. Our equation of forces is now:

$$Mg = Ap + \pi r_1^2 p_1 + (\pi r_2^2 - \pi r_1^2)(p_1 - p) + \left\{\begin{array}{c}\text{A force of unknown}\\ \text{amount due to the}\\ \text{"covered" part of}\\ \text{the valve.}\end{array}\right\}$$

If a thick valve-stem were used one could find a high applied pressure at which the valve would completely close, due entirely to the forces on the valve-stem alone. We therefore conclude that at the central opening the valve-stem must be as narrow as possible, so that $\pi r_1^2 (P_1 - P_0)$ may be vanishingly small at all ordinary applied pressures. Striking out πr_1^2 we have:

$$Mg = Ap + \pi r_2^2 (p_1 - p) + \left\{\begin{array}{c}\text{A force of unknown amount due to the}\\ \text{"covered" part of the valve.}\end{array}\right\}$$

This unknown term cannot be very large, since the pressure difference over the two surfaces is always less than $(P_1 - P_2)$, and the area lies between the radii r_2 and r_3. Its effect will be to increase the effective radius of the valve opening from r_2 to r, where r is greater than r_2 but less than r_3. Putting $\pi r^2 = a$, the effective area, we have:

$$Mg = Ap + a(p_1 - p)$$

$$\text{or } p = \frac{Mg - ap_1}{A - a} = \frac{Mg}{A}\left(\frac{1 - \frac{ap_1}{Mg}}{1 - \frac{a}{A}}\right)$$

Comparing this with the simpler equation $p = \frac{Mg}{A}$ we notice that the two graphs start at the same point $p_1 = p = \frac{Mg}{A}$, and then pursue different paths as p_1 increases. The first is a straight line parallel to the axis of applied pressure; the second is a straight line inclined downwards as p_1 increases, and then $p_1 = \frac{Mg}{a}$, that is, when the applied pressure on the valve alone is sufficient to close the valve, the outlet pressure will be zero. The magnitude of this downward gradient is obtained by differentiation:

$$\frac{dp}{dp_1} = -\frac{a}{A - a} = -\frac{\frac{a}{A}}{\left(1 - \frac{a}{A}\right)}$$

For example, if the equivalent valve area is one-tenth that of the equivalent diaphragm area, $-\frac{dp}{dp_1} = \frac{1}{9}$—*i.e.*, an increase in the applied pressure of 9 in. W.G. will cause a fall in the outlet pressure of 1 in.

Our first two conclusions are:

(1) The valve-stem must be as thin as possible when it traverses the central opening.
(2) The diaphragm area must be made as great as possible in comparison to the valve area.

This equation clearly offers an explanation of the general shape of fig. 2.

Equivalent Diaphragm Area.

When in equilibrium the pan is supported by two forces—(1) the pressure of the gas on the underside of the pan itself, and (2) a small force due to the tension of the diaphragm pulling on the circumference. The pan may be at any one of a number of positions, depending on the consumption. A perfectly flexible diaphragm will assume under the action of a uniform pressure a shape of circular section. If, as usually happens, the diaphragm is only a narrow annular strip round the pan, we can consider it as a part of a cylindrical surface bent into a ring. Our problem is rather similar to the case of a man deposited on the top of a softly inflated balloon, or of a sailor leaning against the leeward side of a distended sail. In each case the forces acting on the man consist of a direct force on his body, and a tensional force due to the stretched membrane. It can be shown quite simply that a cylindrical surface of radius R stretched by a uniform pressure of p poundals per sq. ft. will contain a tangential tension of T poundals per ft., given by

$$p = \frac{T}{R}$$

When the pan is in the mean position the vertical component of the tension tending to lift the pan will be $T \sin\theta$ per unit length—*i.e.*, $\frac{1}{2}T \cdot \frac{AB}{K}$ where AB is the length of the chord from the outer fixing ring to the circumference of the pan.

$$\tfrac{1}{2}T \cdot \frac{AB}{R} = \tfrac{1}{2}pR \cdot \frac{AB}{R} = \tfrac{1}{2}p \cdot AB.$$

This force per unit length acts over the whole circumference of the pan. Let the radius of the pan be K and the radius of the whole diaphragm and pan be $(K + f)$. Then to a first approximation $f = AB$.

Upward force on pan due to diaphragm	$= 2\pi K \cdot \frac{1}{2}pAB.$
	$= \pi K.fp.$
Upward force on pan due to pressure	$= \pi K^2 p.$
Then total upward force on pan	$= p.\pi K(K + f).$
Equivalent area of pan	$= \pi K(K + f).$

= Geometric mean between πK^2 and $\pi (K + f)^2$ - *i.e.*, between the area of the pan and the area of the pan and diaphragm.

For example, in a governor having a diaphragm of diameter 6 in., and a pan of diameter 4 in., the equivalent diameter is $\sqrt{6 \times 4}$—*i.e.*, $\sqrt{24}$, or about 4·9 in., slightly less than the arithmetic mean.

After this paper was first written Mr. Pinkess, of the Gas Light and Coke Company, drew my attention to the fact that this relation did not hold exactly when the pan was above or below its mean position.

Equivalent Valve Area.

Owing to the acceleration of the gas as it passes over the valve towards the central opening, the pressure will fall as the velocity increases, and the total forces acting on the valve can only be obtained by integration. Two cases have been worked out. Let the area of the central opening be a_0, the actual area of the valve a_1, and the equivalent area a.

Then for a disc valve	$a = a_0\left\{1 + \log_e \frac{a_1}{a_0}\right\}$
With a conical valve of any angle	$a = a_0\left\{2 - \frac{a_0}{a_1}\right\}$

Plane Disc Valve.		Conical Valve of any Angle.	
a_1.	a.	a_1.	a.
a_0	a_0	a_0	a_0
$2{\cdot}72a_0$	$2a_0$	$1{\cdot}5a_0$	
$7{\cdot}4\ a_0$	$3a_0$	$1{\cdot}67a_0$	
&c.	&c.	infinite	$2{\cdot}0a_0$

The error due to valve size is therefore very considerable, and except when a_1 is very near to a_0, the conical valve is always better than the disc valve. Whereas the error with a disc valve goes on increasing slowly as the valve size is increased, the error with a conical valve can never exceed a certain amount. The equivalent area can never be more than double the minimum area.

A very interesting alternative to the leather diaphragm is the metal bell carried in a mercury seal. The effective area of the weight pan is in this case the actual internal area of the bell. Otherwise there is little difference in the theory of the instrument.

Elimination of Valve Effect.

Several ingenious expedients have been devised to counteract the reduction of outlet pressure due to the additional forces on the valve. In one form the valve is doubled in such a way that the inlet pressure is exerted in opposite directions on two valves of equal size, thus eliminating the error due to the valve. This type necessarily requires very careful construction. Possibly this was the reason which led to the introduction of another form, which although making use of the same principle, only requires the seating of one valve. In this instrument the inlet pressure acts downward on the valve, and upward on a small diaphragm seal, the chamber under the main diaphragm being a sort of *cul-de-sac* communicating by a small channel with the outlet. If the effective areas of the valve and diaphragm seal are equal the valve error is eliminated.

With a constant pressure governor the makers usually issue an instruction that the instrument should be carefully levelled. Since the opening of the valve is relatively very small, an inclination of only a few degrees will cause the valve to touch the seating at one point. At normal consumptions, or at high applied pressures, the valve will be drawn up against the seating until the turning moments about the point of contact are equal. The inclination of the governor leaves the lifting moment due to pressure unaffected, but the downward moment due to weight acts on a shorter arm, owing to the fact that the centre of gravity is above the valve, and the valve-stem and valve are rigidly connected. Neglecting, for simplicity, the correction due to the valve, we find that the simple formula

$$p = \frac{Mg}{A}$$

becomes

$$p = \frac{Mg}{A}\left\{\cos\beta - \frac{L}{r_3}\sin\beta\right\}$$

or approximately at very small inclinations

$$p = \frac{Mg}{A}\left(1 - \frac{L}{r_3}\sin\beta\right)$$

where β is the angle of inclination of the governor axis to the vertical, r_3 is the valve radius, and L is the height of the centre of gravity of the weight pan and valve above the plane of the valve seating.

When

$$\tan\beta = \frac{r_3}{L}, \quad p = 0.$$

We see that an inclination *reduces* the outlet pressure, and that when the centre of gravity is vertically above the point of contact the valve will close completely. In small domestic governors, designed for a fixed outlet pressure, the weight should be so distributed between pan and valve that the centre of gravity is very close to the plane of the valve. Alternatively, of course, the valve-stem can make a loose coupling with either the valve or the weight pan. Either method would eliminate the error due to tilting.

It will be seen that to locate the valve by extending the valve-stem below the valve into a bearing would reduce the error, the equation being then

$$p = \frac{Mg}{A}\cos\beta$$

but the fault would not be eliminated.

Effect of Consumption on Outlet Pressure.

It is an experimental fact that increase of consumption at constant inlet pressure tends to lower the outlet pressure. As a first precaution the inlet, central opening, and outlet should be made amply large enough for any required consumption. A useful rule is to use in each case an area that would require a pressure of less than $\frac{1}{10}$ th in. W.G. to accelerate the gas from rest to pass through the aperture at the required rate of flow. But even when the governor has been well designed there still remains a small rate of loss of pressure with increasing consumption. Fig. 4 shows the behaviour of a well-made governor at various gas rates.

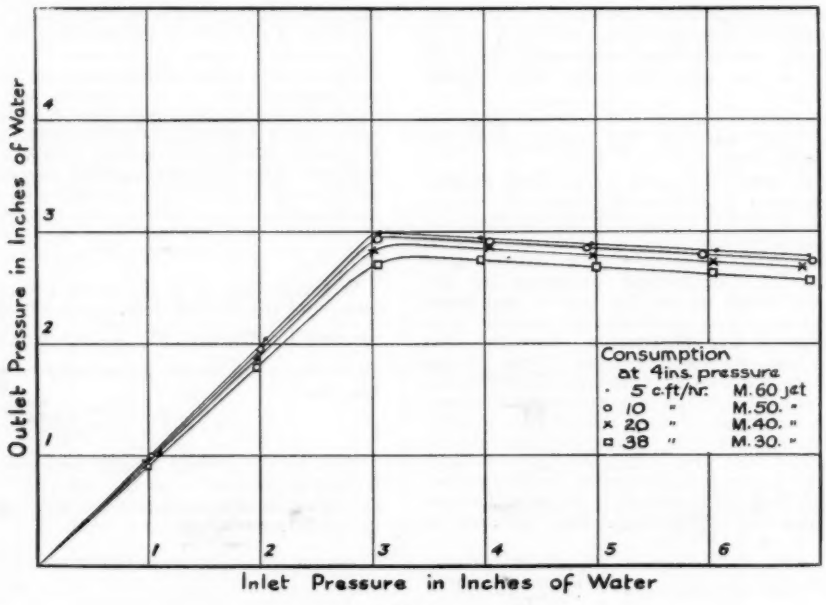


FIG. 4.

A body of gas of density ρ moving at a velocity v is said to have a momentum ρv per unit volume. Force must be used to change momentum. In other words a surface deflecting a moving mass of gas opposes a pressure due to the enforced change of momentum. The force exerted is proportional to the rate of change of momentum. If Q volumes of gas escaping from an orifice of equivalent area f in unit time were turned by a suitable surface through 90°, the rate of change of momentum would be $Q.\rho\frac{Q}{f}$ or $\rho\frac{Q^2}{f}$.

In all practical cases the force exerted is $K\rho\frac{Q^2}{f}$, where K is a fraction depending on the form of the obstacle. In most simple constant pressure governors the gas on leaving the valve encounters the under-part of the weight-pan, or an enlargement of the valve-stem. Thus the equation of equilibrium is really

$$Mg = pA + (p_1 - p)a + K.\rho\frac{Q^2}{f}$$

Now f is a dependent variable, depending on both Q and $(p_o - p)$. Putting f into terms of these variables, we have:

$$Mg = pA + (p_1 - p)a + K Q \sqrt{\frac{2(p_1 - p)}{\rho}}$$

This equation shows that the effect due to inlet pressure is further complicated by this dynamic effect, but that at constant inlet pressure the latter effect is directly proportional to the consumption. To eliminate this, one must prevent the gas leaving the valve from striking any support of the weight-pan. The type of governor with reversed valve has a big advantage in this respect.

Vibration of Governor Diaphragm.

It sometimes happens that a constant pressure governor when in operation emits a " chattering " or " drumming " sound—a matter of some concern in a private house. For the explanation of this phenomenon we must dip into a rather more advanced branch of physical theory. We have seen that one of the basic principles on which a governor works is that " any disturbance from the mean position immediately gives rise to a resisting force tending to restore the conditions to normal." Now since the valve and diaphragm have inertia or mass, in returning they will tend to overshoot the mean position, thus giving rise to another restoring force in the opposite direction.

Since all vibrating systems are subject to frictional resistance, all examples of maintained vibration must depend on sources of energy to make good the frictional losses. In a clock a weight gradually falls, in order to keep the pendulum moving. In an organ-pipe energy is provided by an air-jet at the base. Now in a governor we also have an air-jet at the base, which may act as the source of energy, and, what is still more significant, the air-jet would operate at a phase-difference of a quarter-vibration with respect to the diaphragm. Our only problem is to find out what system it is maintaining. In any system of this kind there are two parts, the spring-effect and the mass-effect, and it can be shown that in vibration it will oscillate according to the law:

$$\text{Time of one complete vibration} = 2\pi \sqrt{\frac{\text{Total mass in motion.}}{\text{Restoring force at unit displacement.}}}$$

The problem is not a simple one, but it can be shown that the mass in question is the mass M which we have already used, and the restoring force is the instantaneous compression or rarefaction of the gas in the chamber below the diaphragm due to the motion of the diaphragm. An example is worked out showing that:

$$n = \frac{cA}{2\pi} \sqrt{\frac{\rho}{VM}}$$

where n = frequency of vibration in number per second.
c = velocity of sound in coal gas in ft. per second.
ρ = density of coal gas in lbs. per c.ft.
A = effective piston area of diaphragm and pan.
V = volume of chamber below diaphragm in c.ft.
M = mass of diaphragm and valve, in lbs.

Assuming that the chamber below the diaphragm is cylindrical and of depth h, and that the valve error is compensated, the frequency equation simplifies rather surprisingly to:

$$n = \frac{c}{2\pi} \sqrt{\frac{\rho g}{p\,h}} \quad \text{(approximately)}$$

where p is the governed pressure. Any governor having an equivalent chamber depth of 1 in., and governing to 2 in. W.G., will tend to vibrate at about 60 vibrations per second—*i.e.*, about two octaves below Middle C, a low humming note which with mechanical noise would sound as a drumming or buzzing noise, very distressing to sensitive ears.

To eliminate this resonant vibration, one has only to increase the frictional losses, and also the force losses, until the motion becomes dead-beat. To increase the force losses, the outlet from the diaphragm chamber must be made as large as possible. It is in this one connection that the reversed-valve type of governor is usually very badly designed. The communication with the diaphragm chamber should be a large hole, not a small one. In simple acting governors vibration is scarcely possible, unless the outlet is throttled. To increase the frictional losses the system can be given a " dash-pot," but this is open to certain objections. The usual practice of making the communication with the atmosphere above the diaphragm a very small hole is of limited value. It prevents violent movements of the valve, and safeguards governors in transit, but it creates another resonant chamber, producing in effect a double resonator, and may actually increase the liability to vibrate.

Constant Volume Governors.

Fig. 5 shows the type of small constant volume governor used on appliances such as the Cannon " Beacon " radiator. Gas enters at a, and encounters the under-side of a metal piston or float e. When the inlet pressure P_1 is extremely small gas will flow through the orifice d and out by the ports f to the outlet h. If P_1 is increased sufficiently, the float e will rise, until its upper edge has constricted the ports f to such an extent that the inlet pressure is only just able to support the float against the back pressure above the float. In this condition the weight of the float distributed over its total area produces a difference of pressure between the two sides of the orifice d which is exactly

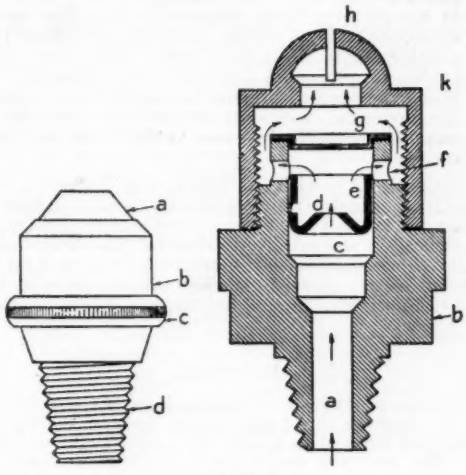


Fig. 5.

equal to the loss of pressure caused by the passage of a certain gas-rate through d. Using the same nomenclature as before:

$$Mg = A(P_1 - P_2)$$

and $P_1 - P_2 = \frac{1}{2}\rho \frac{Q^2}{c^2}$, where c is the equivalent area of the orifice d,

i.e., $Q^2 = \frac{2Mg\,c^2}{\rho A}$, or $Q = c\sqrt{\frac{2}{\rho} \cdot \frac{Mg}{A}}$

Since in a given governor, c, Mg, and A are fixed, the gas rate Q can only vary with variations in the density ρ. With constant density, the instrument may be truly called a constant volume governor. There is no diaphragm or valve-error, as in the constant pressure governor, and the instrument is remarkable for its accuracy in maintaining a constant gas-rate, provided the density does not vary.

Calculation of Minimum Working Pressure.

In contrast with the constant pressure governor, which can be made to offer a negligible resistance at low applied pressures, the constant volume governor always opposes a considerable resistance to flow. Let the total available pressure difference be $P_1 - P_0 = p_1$.

Let the equivalent areas of the orifice d, the ports f when fully open, and the burner or injector orifice h (depending on whether a luminous or aerated burner is attached) be c, K, and S respectively.

Then

$$p_1 = \tfrac{1}{2}\rho Q^2 \left\{ \frac{1}{c^2} + \frac{1}{K^2} + \frac{1}{S^2} \right\}$$

If it is necessary to provide a gas-rate Q under a definite jet-pressure p', then the term $\frac{1}{2}\rho \frac{Q^2}{S^2}$ can be replaced by p'. Also the term $\frac{1}{2}\rho \frac{Q^2}{c^2}$ can be replaced by $\frac{Mg}{A}$.

Then

$$p_1 = p' + \frac{Mg}{A} + \tfrac{1}{2}\rho \frac{Q^2}{K^2}$$

Therefore to supply a constant rate of flow Q at a certain jet-pressure p', the applied pressure must be greater than p', by an amount $\left(\frac{Mg}{A} + \frac{1}{2}\rho \frac{Q^2}{K^2}\right)$. $\left(\frac{Mg}{A}\right)$ can be made small by increasing the diameter, and reducing the weight of the bell. By using a thin aluminium float, $\frac{Mg}{A}$ can be materially reduced; but since 1 in. of water is only about $\frac{1}{2}$ oz. per sq. in., it is clearly impossible to reduce $\frac{Mg}{A}$ to less than a few tenths. The last term $\frac{1}{2}\rho \frac{Q^2}{K^2}$ can be made small by making K as large as possible, but in practice it is difficult to make $\frac{1}{2}\rho \frac{Q^2}{K^2}$ less than one or two

tenths. The result is that the minimum pressure at which a constant volume governor will operate is never less than 5 tenths greater than the pressure required at the outlet, and may be 10 or even 20 tenths in small instruments, where $\frac{Mg}{A}$ tends to be large.

The effect of leakage round the float may be summarized thus:

(1) At low applied pressures the variable orifice K will be large, and therefore its resistance will be small, and the leakage can be considered as a fixed orifice in parallel with the float orifice C. The governor therefore behaves at low pressures as though C were greater than its actual size. Otherwise the accuracy of governing is not seriously affected.

(2) When the applied pressure is increased considerably, the governor ceases to be accurate, and the consumption steadily increases as the pressure is further increased.

In conclusion, I wish to thank the Directors of the Cannon Iron Foundries for permission to publish this work, and also to acknowledge my indebtedness to Mr. J. G. Clark, whose Presidential Address to this Association in October, 1911, constitutes the only other theoretical paper in English on gas governors. My thanks are also due to Mr. C. J. Moore who carried out the experiments described in the paper.

Discussion.

The PRESIDENT (Mr. H. C. Sims, Assoc.M.Inst.C.E., of the South Metropolitan Gas Company), in opening the discussion, said they had listened to a most interesting paper on gas governors. The governor was a piece of apparatus, he thought, in regard to the functions of which many of them had somewhat confused ideas—so that what Mr. Benton had said would rather clarify their outlook. The function of a governor, said Mr. Sims, was to maintain either a constant pressure or a constant volume. He took it that when a governor was being fitted on a consumer's premises account had to be taken of the maximum volume of gas likely to be required.

Mr. BENTON replied that this was so.

BALANCE BETWEEN THEORY AND PRACTICE.

Mr. H. J. HADOW, B.A., B.Sc. (Oxon) (Gas Light and Coke Company), said that the Gas Industry should be sincerely grateful to Mr. Benton for opening up a subject upon which so very little had been published as yet. At Watson House they were continually working on governors and governing, and a number of types had been designed, working from a theoretical basis, and had proved to have the performance expected of them. The balance between theory and practice was their especial field, and to provide some link between these two aspects would, he hoped, make the true value of Mr. Benton's paper more apparent, though he apologized to him for so diverting from pure theory.

A constant pressure at the burners of an appliance was of advantage in a large number of ways. In designing all gas burning appliances, two interdependent factors were strongly influenced by the supply pressure. These were efficiency and completeness of combustion, and the second of these was of primary importance and controlled the first. Increasing pressure and thus increasing gas rate resulted, in some cases, in the quantity of carbon monoxide increasing beyond the danger point, and if such fluctuations were to be expected on the district, the design must be condemned or modified to include a greater overload. This modification probably resulted in a small decrease in the efficiency, and it followed, as a secondary result, that a constant pressure and thus an assured gas rate enabled more efficient apparatus to be made use of.

Fixed injectors could be incorporated with no air control or pressure adjustment and a cheaper appliance which could not be so easily tampered with became possible. In this connection, it should be noted that the specific gravity must be kept constant.

ADVANTAGES ON THE DISTRICT.

Of greater importance were the advantages gained on district during fitting and use. Apparatus fitted with fixed injectors and governors could be installed without time being wasted on adjustments. Once burning, there was no danger of over-gassing and direct damage to the metal work; corrosion would be at a minimum (on water heaters at least this increased with the consumption); scaling was reduced and maintenance minimized. Of all appliances, an assurance could be given to consumers of a fixed running cost and a fixed heat output. In fact, the use of reliable governors enabled a much improved service to be offered to the consumer.

It might be said that district pressures did not vary sufficiently to warrant the use of point governors. Over and above these distribution fluctuations must be set the inconstant pressure drops in the average house carcass; a governor often enabling use to be made of a carcass inadequate without one. Many people did not consider it worth while complaining to the Company of "bad gas" or roaring burners, but the elimination of these sources of dissatisfaction would undoubtedly increase the goodwill of the consumer.

The theory of governors had been applied to a considerable extent in the design of almost all types of governors. The theory of perfection and economical design had, as usual, to effect a compromise, and in the former case use could be made of calculation to obtain figures for diaphragm area, valve area, and position of centre of gravity. When the actual model was considered, there were several points of practical importance which would not be lost sight of. Of these: (1) Resistance of connection and valve, (2) accessibility of parts and ease of maintenance, (3) protection of breather hole for blockage, (4) suitability of leather and dressing, and (5) manufacturing limits, were worthy of the most careful consideration. The manufacturing tolerances which could be allowed without interfering with the performance were all important, but were almost the subject of a paper in themselves.

Returning at last to pure theory, using a valve of vertical angle about 90° and in area not very much larger than the seating, they had found that the area of this seating could be taken as the area over which the inlet pressure acted and tended to close the valve. The results on several governors bore this out. On a ½-in. cooker governor, the fall off in outlet pressure was calculated as 1 in. for a 5·5 in. increase in inlet; in fact, it proved to be 5·3 in. On an experimental governor the calculated and observed values agreed at 40.

Mr. L. H. PINKESS (Gas Light and Coke Company) thanked Mr. Benton for his very interesting analysis of the factors underlying the design of governors. The paper had provoked a good deal of thought and had shown in an admirable fashion how a tricky subject could be reduced to a few useful formulæ; that governors were not on the one hand clumsy rule of thumb jobs or on the other hand mysterious boxes of tricks quite beyond the comprehension of ordinary mortals. The study of governors was one to which they could all profitably devote some time, if only to get the right sense of proportion as to their value and their limitations. They had known the old school of inspectors whose remedy for every kind of governor defect was a large piece of paper or wood placed under a cap to jamb the valve open. Mr. Penkess said he had spent a large part of two or three years on the design of governors at Watson House, and he would like to show how, by using simple formulæ such as Mr. Benton's, they could anticipate the performance of a governor with some accuracy.

EFFECTIVE DIAPHRAGM AREA.

With reference to the effective area of the diaphragm, Mr. Benton had worked his formula on certain assumptions—namely, that the portion of the leather between the pan and the fixed edge formed a part of a circular cylinder, and that the diaphragm was of perfectly flexible material. The assumptions were made for the very good and sufficient reason that the mathematics of a perfect diaphragm were already complicated, and if all the practical factors were included the calculations would become really formidable. Let them then see what were the practical limitations to his formula.

For small governors, at any rate, the fact that the radius of the diaphragm plates was not immensely greater than the radius of curvature of the bulge, introduced error due to two dimensional curvature. At Watson House they had found it a very convenient approximation to assume that the leather took up the form of two truncated cones, one with its vertex upwards and one with its vertex downwards, meeting along the crest of the leather bulge. If they thought that out they would see that it postulated an unstretchable leather. Then they took the diameter of the highest point of the bulge as the effective diameter of the diaphragm. Neither Mr. Benton's approximation nor the Watson House approximation was really accurate, since the leather stretched to a limited extent, and some compromise had always to be made; but these approximations formed useful bases for the calculation of the performance of a governor. They would see that the slack of the leather—that was to say, the distance through which the leather could move without stretching—was important whichever approximate formula they used.

BIAS IN THE LEATHER.

There was another point of some practical importance in very small governors. If a leather blank was mounted between card rings and the requisite slack was given by making the former bend the leather into a bulge, and particularly if the bend started close to the rings, there would always be a bias in the leather towards the position in which it was formed. The extent of the bias would depend on the inherent flexibility of the leather, and that in turn on the preparation of the leather, and so on; but it was largely an edge effect, and only altered the outlet pressure in very small governors. In larger ones the working forces very greatly exceeded the bias forces.

While speaking of diaphragms it would be convenient to mention the fall of outlet pressure with increasing gas rate. Mr. Benton had attributed this very largely, if not entirely, to an impact effect created when the high-velocity gas stream coming past the valve impinged on the diaphagm plates. Mr. Pinkess did not think this factor was normally very large, and would suggest another. When a governor valve opened to accommodate a large flow of gas, the centre of the diaphragm fell, and the effective diameter of the diaphragm increased. Consequently the pressure necessary to support the weight of the moving parts fell. To take an example, he had with him a graph showing the performance of an actual diaphragm. The pressure necessary to maintain the diaphragm in any given position, and the corresponding effective diameter were plotted, and a ¾ in. governor had a diaphragm similar to that on which he made the graph. Using a constant inlet pressure of 7½ in., the fall of outlet pressure measured at a point on the outlet connection between 10 and 200 c.ft./hour was 0·25 in. Of this

0·1 in. could be directly accounted for by the change in effective area of the diaphragm as the valve opened, even though the valve movement was no more than 1/32 in. Of the remaining 0·15 in., approximately 0·1 in. can be accounted for by pressure loss between the diaphragm chamber and the pressure point, and the rest might be due to the dynamic effect of which Mr. Benton spoke.

The compensated Bryan Donkin governor showed a fall of outlet pressure with increasing gas rate, although the gas passed downwards past the valve and did not impinge at high velocity on the moving parts. He thought it was true to say that changes in effective area of diaphragm were almost always a larger factor than the velocity effect in producing the fall of outlet pressure with increasing gas rate.

Valve Shape.

Another thing which was bound up in this fall of outlet pressure with increasing gas rate was the valve shape. If they used a flat plate for a valve, the movement of the valve for a given opening would be comparatively small, while if they used a cone valve with a very small vertical angle, it would have to move much farther down than would the plate valve to give the same effective area opening. It had been pointed out that the effective area increased and the outlet pressure decreased as the valve moved downwards, and so the change of pressure for a given increase in gas rate would be greater in a governor with a cone valve with a small vertical angle than in a governor with a plate valve. By using a valve of carefully calculated cone slope a governor had been made in which the tendency for the outlet pressure to fall with increasing gas rate had been neutralized by the tendency for the outlet pressure to rise owing to the change in effective area of the diaphragm. In reference to the effect of tilting a governor. Mr. Benton had developed a very interesting reasoning about the tilting movement applied to the valve. Mr. Pinkess had with him a graph showing the way in which the outlet pressure of a G.L.C. ½ in. cooker governor varied with the angle of tilt. The centre of gravity was fairly high, and the critical angle of tilt from Mr. Benton's point of view was about 25°.

The outlet pressure rose steadily as the angle of tilt increased up to 30°, and then fell off till it was zero at 80°. It was interesting to note that the rise of pressure was like that which would be expected from the assumption that the effective area decreased with increasing angle of tilt according to the cosine of the angle. The fact that the maximum pressure occurred where Mr. Benton would seem to expect a minimum showed that the factors he had explained did not form the whole story.

Chattering.

Mr. Benton raised an interesting point about the outlet from the diaphragm chamber being made large if one wished to avoid chattering. They had noticed how some examples of the reversed valve governors chattered much more than others, even though they were from the same batch of delivery. The cause probably lay in the fact that the outlet from the diaphragm chamber passed through a hole in a leather washer and the degree of blockage varied from one governor to another. Mr. Benton spoke a little disparagingly of the method of checking chattering by using a chamber over the diaphragm with a small breathing hole. It was just because this space did form another resonance chamber that it was of value. To be effective, the chamber above the diaphragm must be as small as possible in order to make the restoring forces large, and for the same reason the breathing hole must be small. But, as Mr. Benton indicated, the resonance period of the chamber must not be such as to aggravate chattering. This could only occur if the resonance period of the upper chamber was an odd harmonic of the resonance period of the lower chamber.

Governors and Street Lighting.

Mr. F. C. Smith (Gas Light and Coke Company), the Senior Vice-President, remarked that there was a great deal they could learn from the paper in regard to the constructional features of gas governors. He felt that the Gas Industry did not place sufficient value upon these appliances; the electrical industry would be only too pleased to have such an apparatus as this to control their pressure. He went on to refer to the value of governors in street lighting where one was maintaining a set illumination figure. An increase of 5% in the voltage, for instance, resulted in a light increase of 33%—but it greatly lessened the life of the bulbs, which was an exceedingly serious matter to electrical engineers endeavouring to design street lighting installations. They would be only too happy to make use of so simple an appliance as a governor. In most electrical problems the effect varied as the square of the voltage difference; but in the Gas Industry it varied as the root; so their governors need not be so precise while still maintaining the supply to appliances constant. They rated appliances in terms of CO/CO_2 ratio, and that ratio must not exceed a certain amount with a pressure load of 100% safeguarding themselves against inadequate carcassing. But by utilizing governors they could work at 50% load and so rate up the appliances, making them do more work and thus lowering the capital cost. So distribution men should do all they could to further the use of governors; it was a very inexpensive piece of apparatus and was extremely effective in bringing about the desired result.

Mr. D. M. Holloway (Gas Light and Coke Company) said that if the diaphragm was taken in a symmetrical position as assumed in the paper, then at the highest points, which would be at points on a circle having as radius the *arithmetic* mean of pan radius and full radius, the tangent would be horizontal. Thus the centre of the diaphragm could be isolated by cutting round this circle without affecting the vertical forces on it, and the area of this central portion was therefore clearly the equivalent area of the diaphragm. This did not agree with the result derived in the paper since it gave the arithmetic mean instead of the geometric. The discrepancy would appear to lie in the assumptions, in the method used in the paper, that the annulus acted as a cylinder of equal "length."

Referring to a diagram shown, in which the valve was hanging vertically from a tilted diaphragm (as would happen if a pivot attachment to the diaphragm were provided), and only just touching the seating, in connection with which it was stated that in this case the governor would give the normal pressure, Mr. Holloway said this would not be so, as the vertical force on the diaphragm would be equal to the pressure multiplied by the horizontal projection of the equivalent area which would be less than the normal area. The pressure would therefore be higher, as was confirmed by the experimental results shown by Mr. Pinkess. In the other case of tilting discussed it was suggested that the valve would close completely when the centre of gravity was vertically above the point of contact. This would, he thought, be a case of unstable equilibrium as the valve would immediately pivot on to the opposite edge of the seating and would in that position give a pressure higher than normal owing to the bob weight acting on a longer arm.

Mr. E. A. Laundy (South Metropolitan Gas Company) said that the total downward weight equalled the area of the diaphragm multiplied by the upward pressure. Then there was the matter of inertia to be considered, and he wondered what effect this inertia had on the outlet pressure.

Mr. P. Richbell (Croydon), called upon by the President to contribute to the discussion, remarked that he gave his attention more to large district governors, the working conditions of which were rather different from those of the governors dealt with by Mr. Benton. The method of application of pressure was quite different, while, again, in regard to the actual area of the valves, large governors very seldom gave a full area to the main feeding them.

The Author's Reply.

Mr. Benton, replying to the discussion, thanked the contributors for their kindly comments on his paper. If the mathematical methods used were unfamiliar to some of the members, he thought that when they had an opportunity of reading the published account they would not find any difficulty in understanding them. Formulæ were used not for the purpose of complicating a subject, but in order to clarify their facts, and enable them to come to conclusions otherwise undiscoverable. When a theoretical process led to a wrong result, it was not the mathematical method which was at fault, but the initial assumptions used. By taking great care with the assumptions, formulæ could be obtained showing an increasingly closer agreement with the truth.

Mr. Smith had expressed very ably the remarkable advantage gas had over the electrical industry in the possession of governing devices. Mr. Hadow's remarks on the practical importance of governors were also a valuable supplement to the paper. There was, of course, a great variety of ingenious governing devices of varying degrees of merit. As an appliance maker, the author did not feel himself entitled to express an opinion on any particular form of governor, and had confined himself to general principles.

After this paper was originally written, Mr. Pinkess had drawn the author's attention to the fact that part at least of the loss of pressure due to increasing consumption was due to the alteration in the effective diaphragm area as the position of the pan relative to the circumference of the diaphragm was altered. After going into the matter carefully, he agreed with Mr. Pinkess that the effective diaphragm area varied with the position of the pan, but that the variation was least when the pan was level with the circumference, the graph of the variation showing a point of inflection at this condition, and when the slack in the diaphragm was sufficient to produce a semi-circular section at the mean position, the variation was zero for small movements to either side of the mean position. Except at the mean position the gradient $\frac{dp}{dQ}$ was unfortunately always negative. The "long-cone" valve which Mr. Pinkess had mentioned was a remarkable achievement, and showed both the truth of the theory, and also an ingenious method of matching two defects one against the other. Actually the cone should not have a perfectly straight side, but a peculiar wave-form, which, however, would be quite impossible to make in practice. The author showed how the addition of a dynamic effect to the theoretical "pan-position" curve gave a complete explanation of the theoretical curve shown by Mr. Pinkess.

Effect of Tilting a Governor.

The effect of tilting a governor was clearly more complicated than the simple formula assumed, and it would be very instructive to find the cause of the deviations to which Mr. Pinkess had drawn attention.

The influence of the vent-hole on chattering could only be through its influence on the natural period of the upper chamber as a resonator, and must not be confused with its damping effect on the motion of the valve. The hole should be small in order to use the upper chamber as a "dash-pot," and one was therefore forced to take into consideration the co-operation or interference of two resonating cavities. If they could make the vent-hole large they would eliminate the upper resonance. Mr. Pinkess's remark that the upper cavity should be as small as possible was very interesting. This clearly meant that such

a construction caused opposition rather than re-inforcement between the two resonances. The general theory of double resonance was dealt with by the author in an appendix to Paget's "Human Speech."

Mr. Holloway considered that at the mean position the effective-radius of the diaphragm was the arithmetic mean of the radii of pan and diaphragm. Mr. Benton explained that it could not be other than the geometric mean, which satisfied the principle of "virtual work." He agreed with Mr. Holloway that the simple equation for tilting did not offer a complete solution.

Replying to Mr. Laundy, the author explained that whereas the weight of the pan and valve was a controlling factor in determining the outlet pressure, mass, or inertia, as distinct from weight, could only be concerned in the tendency to chatter. Increased mass lowered the frequency.

VOTE OF THANKS.

Mr. F. C. SMITH proposed a vote of thanks to Mr. Benton for his very interesting lecture, which was seconded by Mr. J. M. WEBBER (Croydon), the Junior Vice-President, and heartily accorded

Mr. BENTON, in acknowledgment, said that the Junior Associations offered the only opportunity for appliance manufacturers to meet members of the Gas Industry, enabling that co-operation between them and gas undertakings which was so important to the future development of the Industry.

REGISTER OF PATENTS

Gasholders.—No. 390,781.

MASCHINENFABRIK AUGSBURG-NURNBERG A.G., of Nürnberg.

No. 35,874; Dec. 17, 1932. Convention date, Dec. 17, 1931.

It has been proposed to construct a bell gasholder in such a manner that the bottom is provided at its outer edge with a stationary seal which bears against the bell inverted over the bottom, the space above the bottom serving as the gas space. In such an arrangement the bottom may be placed in an elevated position and rest on supports. The bell is carried by the gas pressure and the cover structure of the bell is loaded by the weight of the shell of the bell, which is concentrated at the edge of the cover. When the bell is in its lowest position—that is, when the holder is empty—the bell cover rests on the elevated bottom and the shell hangs down freely without itself having support.

A substantial improvement from the static point of view is obtained if a loading weight be placed in the centre of the bell cover. This simple expedient results in the influence of the weight of the shell on the bending moments in the cover structure being greatly reduced. With a suitable weight, for instance, the bending moments in the middle of the cover are reduced to about one-quarter of their former value.

The useful effect of the central loading weight becomes particularly apparent when the bell in its empty state rests on the bottom. In this case the bell cover is loaded at its edge by the weight of the shell of the bell and the stresses caused thereby in the bottom of the holder are then equalized by the central loading weight. This effect is a peculiarity of the holder construction according to the invention and cannot occur, for instance, in the earlier bell gasholders with a water basin.

Oven Thermostats.—No. 393,775.

RADIATION LIMITED, of Birmingham, and YATES, H. J., of Grosvenor Place, S.W. 1.

No. 20,040; July 15, 1932.

The object of this invention is to provide an improved oven thermostat which affords easy access to the valve for cleaning, is of simple construction, and is capable of being easily manufactured and assembled.

If the action of the valve should be interfered with by a particle of dirt carried on to the valve by the gas, movement of the valve by an outward pull on the finger piece may be sufficient to dislodge the obstruction. Should this be insufficient, the cover can readily be detached, and the valve together with the adjusting stem removed without disturbing the adjustment of the device.

Such a control device, state the patentees, is of simple construction, is easily made, and affords all the required convenience in use as well as effecting the required control of the gas in a reliable manner.

Dry Gasholders.—No. 393,887.

DRY GASHOLDERS, LTD., of Victoria Street, S.W. 1.

(Communication from Aug Klönne, of Dortmund.)

No. 735; Jan. 9, 1933.

Owing to the fact that a part of the reactionary pressure opposing the outward thrust applied towards the clamping ring of the sealing annulus by the yielding-pressure elements is constituted by the gas pressure upon the outer surface of the lower portion of the flexible curtain by which the sealing ring is connected to the periphery of the piston, the actual radial pressure of the sealing annulus against the surface of the cylinder tends to vary with the working gas pressure within the holder. Consequently, if standardized construction be employed, as is desirable, for the various parts of these gasholders, an excess of sealing ring pressure over that actually necessary to ensure adequate sealing as between the piston and the cylinder of the holder obtains in those holders where the working gas pressure is of the lesser order of magnitude. Unnecessary wear of the sealing ring results.

Moreover, since the reactionary pressure of the gas upon the flexible curtain is applied always at a point below the sealing annulus, the wear of the latter tends to be greater towards the top of the annulus than towards the bottom.

The object of this invention is to overcome these difficulties simply. Means are provided whereby the point of application of thrust of the yielding-pressure elements upon the sealing ring or the position of the resultant of the thrust may be adjusted towards and away from the piston of the holder, for the purpose of adjusting the value or distribution in the vertical direction of the thrust of the sealing ring against the surface of the cylinder.

Gas Companies' Results in 1933

Cardiff.

The Directors of the Cardiff Gas Light and Coke Company present accounts for the year, which show that an interim dividend to June 30 last having been paid on the consolidated ordinary stock at the rate of 6% per annum, and on the preference stock at the rate of 4½% per annum, the Directors recommend payment of a final dividend for the year on these stocks at the same rates less income-tax. The Directors record with deep regret the death of their colleague Mr. Ernest A. Prosser, a Director since 1927, whose services to the Company have been greatly appreciated.

Ipswich.

The Directors of the Ipswich Gas Light Company submit accounts which show that after payment of the interim dividend at the rate of £6 7s. 6d.% per annum and providing for interest and other charges, there is an available balance of £29,559. The Directors recommend the payment of the following dividends in respect of the December half-year—viz.: At the rate of £6 10s.% per annum on the consolidated stock, and at the rate of £5% per annum on the 5% preference stock, which will absorb the sum of £7281, leaving a balance to carry forward of £22,277. As from the end of the March quarter the price of gas was reduced by 1 4-5d. per 1000 c.ft., equal to £6000 per annum. There was an increase of more than 11 million c.ft. (1·31%) in the quantity of gas sold during the year.

Maidstone (S.E. Gas Corporation).

The accounts of the Maidstone Gas Company for the year show that after paying in respect of the half year a dividend at the rate of 8% per annum on the 5% capital stock and after providing for all fixed charges (including £2000 for depreciation of meters and a contribution to the reserve fund of £2423) there is a total available balance of £20,197, out of which the Directors recommend the payment of the following dividend in respect of the second half year—viz., On the 5% capital stock at the rate of 10% per annum, which will absorb the sum of £6215, leaving £13,982 to be carried forward to the credit of the current year. The sales of gas show an increase of 0·86% over the year 1932.

Malton.

The expenditure in the revenue account of the Malton Gas Company has amounted to £7761, and the receipts to £9537. The profit is less, compared with the corresponding period of 1932, by £127. This decrease is more than off-set by the reduction in the price of gas during the first three months of the period compared with twelve months ago. The gas sold is about the same as twelve months ago. The receipts from coke and tar have been less, but the receipts from asphalting and fittings have been maintained. With the balance of £5696 brought forward from the last accounts, there is a balance, after paying income-tax, of £7072. The Directors recommend

that a dividend of 6¼% free of income-tax be paid for the half-year. This will absorb £1500, and leave the sum of £5572 to be carried forward to the next accounts.

Newport (Mon).

The Directors of the Newport (Mon.) Gas Company submit a report for the year showing that an interim dividend at the statutory rate of 5% per annum on the consolidated stock of the Company, for the half-year ended June 30, 1933, having been paid, it is now recommended that a final dividend at the same rate be declared for the half-year ended Dec. 31, 1933.

Penistone.

The sale of gas by the Penistone and District Gas Company has increased slightly, the therms sold being 106,229 as compared with 104,944 in 1932, an increase of 1285, or 1·22%. The profits for the year amount to £1002, which, with the balance brought forward from the previous year (£121) makes a total of £1124. Interest on debentures absorbs £75, and dividend on preference shares £292, both tax deducted. An interim dividend on the ordinary shares was paid for the June half-year at the rate of 6% per annum, which, less tax, amounted to £225. From the balance (£532) the Directors recommend that a dividend be paid for the December half-year at the rate of 8% per annum, which, less tax, will absorb £300, and leave £232 to be carried forward. During the year £1000 was repaid to debenture holders, reducing the amount outstanding to £1000. No addition to the reserve fund has been made during the year, the amount remaining at £2975. As the expenditure on works, however, has been less than normal, it has been deemed prudent to carry to special purposes fund the amount authorized by Statute of £165, bringing that fund to £1320.

Pudsey.

The sales of gas by the Pudsey Gas Company show a slight decrease when compared with the previous year. The balance of net profit, after deducting the interim dividend at the rate of 9% per annum paid in August last, amounts to the sum of £13,199, from which the Directors recommend a dividend for the past half-year at the rate of 9% per annum.

Sheppy (S.E. Gas Corporation).

The accounts of the Sheppy Gas Company for the year show that, after paying in respect of the first half-year dividends at the rate of: £4% per annum on the "A" preference shares, £5 5s.% per annum on the consolidated ordinary stock, and £6% per annum on the preference stock; and after contributing the sum of £500 to the reserve fund and £500 to the renewal fund, there is a total available balance of £7113, out of which the Directors recommend the payment of the following dividends in respect of the second half-year—viz., on the "A" preference shares at the rate of £4% per annum, on the consolidated ordinary stock at the rate of £5 5s.% per annum, and on the preference stock at the rate of £6% per annum, less income-tax in each case, which will absorb the sum of £2165, leaving £4948 to be carried forward to the credit of the current year. The sale of gas during the past year shows an increase of 6%. There has been an addition for the year to the number of consumers of 141. During the year a new gasholder, of a capacity of 400,000 c.ft., was erected and brought into use.

Southampton.

The Directors of the Southampton Gaslight and Coke Company present accounts for the year which show that interim dividends at the full statutory rates were paid, less tax, on Sept. 1 last, and the Directors now recommend final dividends at similar rates, less income-tax, for the half-year ended Dec. 31, 1933. The sales of gas for the year show an increase of 30,037,900 c.ft., or 1·95%, and the sales of gas cookers, fires, and other appliances have increased to a very large extent. A contract has been placed for the erection of a three-and-a-half million cubic feet gasholder, and good progress has been made with its erection. In December last a benzole plant was brought into operation with satisfactory results. The Southampton Gas Order 1933, was made by the Board of Trade on Dec. 21, 1933. The Order provides for a basic price of gas, and makes provision for the future division of the profits of the Company, in lieu of the former maximum price and dividend.

Weymouth.

Sales of gas by the Weymouth Consumers' Gas Company again show an increase, the amount sold for the year being 1,198,926 therms or 260,636,200 c.ft. This, compared with the previous year, shows an increase of 4,227,200 c.ft., or 1·6%. During the past year the price of gas was reduced, and the Directors propose making a further reduction from the first of January this year. The sales of appliances during the year show a very gratifying increase. The new works which were put into operation during the past year continue to give every satisfaction. The Directors in conjunction with the employees and staff have inaugurated a pension scheme on a contributory basis. All employees will, in future, automatically retire on pension at the age of 65. After providing for the interest on the debenture stock, the balance at the credit of the net revenue account is £4668, out of which the Directors recommend the payment of the following dividends: On the ordinary stock at the rate of 5½% per annum, less the interim dividend already paid to June 30, 1933, less income-tax; and on the 5½% redeemable preference stock at the rate of 5½% per annum, less the interim dividend already paid to June 30, 1933, less income-tax.

Special 3″ Diameter
STANTON-DELAVAUD SPUN IRON PIPE

s. d.
2/1½
NET PER YARD
F.O.T. WORKS

SPECIFICATION

Actual Bore	3·28 ins.
Thickness	0·25 ins.
Length (effective)	4 yards
Weight	1 cwt.
Coating	Coated both sides, outside only, or uncoated

ADVANTAGES

The external diameter of the pipe and the internal diameter of the socket are to British Standard Specification. The increased bore gives an effective carrying capacity approximately 20% greater than that of an ordinary 3-inch diameter Cast Iron Pipe or Steel Tube.

The Spun metal gives a much larger factor of safety than that obtainable in the ordinary sand-cast pipe, and has a considerable degree of elasticity capable of withstanding high stresses.

All these pipes are hydraulically tested to a pressure of 200 lbs. per sq. in. before despatch.

THE STANTON IRONWORKS COMPANY LIMITED, Near NOTTINGHAM

GAS MARKETS & MANUFACTURES

Stock Market Report.

[For Stock and Share List, see later page.]

The intense activity in gold-mining shares, brought about by President Roosevelt's decision to return to a gold bullion standard, was the chief feature on the Stock Exchange last week. Prices moved up substantially, and gold reached £7 an ounce. Other sections were comparatively neglected, and some liquidation was in evidence, particularly in the industrial market, by speculators to provide funds for the purchase of gold shares.

Business in Gas stocks and shares was on a smaller scale than usual, but with few exceptions values remained unchanged. In several instances, however, transactions were recorded at prices which would appear to justify some improvement in the quotations. Inquiries for Uxbridge ordinary led to a rise of 3 to 151½; Swansea 5½ p.ct. preference hardened 1½ to 110½; while Brighton 5%, South Metropolitan 6% preference, and Wandsworth 5% preference all gained 1 point.

Among last week's final dividend announcements appear the following, the rate for the past year in each case being the same as that for 1932:

—	Interim.	Final.	Total.
	%	%	%
Cardiff	3	3	6
Chester	2½	3½	5½
Croydon	3½	3½	7
East Surrey	3	3	6
Newcastle	2½	2⅝	5⅛
South Suburban	3	3	6

The recent issue by the East Hull Gas Company of £60,000 4½% preference stock was nearly three times over-subscribed, and prices ranged from £112 to the minimum of £103%. The lowest tender accepted was at £106 2s. 6d.%, and the average price obtained amounted to £106 16s. 6d.

Current Sales of Gas Products.

The London Market for Tar Products.

LONDON, *Feb.* 5.

There are a few changes to report in the prices of tar products, which are as follows:

Pitch is about 60s. per ton f.o.b.

Creosote, 3d. to 3½d. per gallon.

Refined tar, 4d. to 4¼d. per gallon in bulk at makers' works.

Pure toluole, about 3s.; pure benzole, 1s. 10d. to 1s. 11d.; 95/160 solvent naphtha, about 1s. 9d.; and 90/140 pyridine bases, about 6s.—all per gallon naked at makers' works.

Tar Products in the Provinces.

Feb. 5.

The average prices of gas-works products during the week were: Gas-works tar, 24s. to 29s. Pitch—East Coast, 59s. to 61s. 6d. f.o.b. West Coast—Manchester, Liverpool, Clyde, 59s. to 61s. 6d.* Toluole, naked, North, 2s. 3½d. to 2s. 5½d. Coal-tar crude naphtha, in bulk, North, 6½d. to 6¾d. Solvent naphtha, naked, North, 1s. 6½d. to 1s. 7½d. Heavy naphtha, North, 10½d. to 11d. Creosote, *ex* works, in bulk, North, liquid and salty, 2½d. to 2¾d.; low gravity, 2d. to 2½d.; Scotland, 2½d. to 2¾d. Heavy oils, in bulk, North, 3¾d. to 4¼d. Carbolic acid, 60's, 2s. 1½d. to 2s. 2½d. Naphthalene, £10 to £11. Salts, 55s. to 75s., bags included. Anthracene, "A" quality, 2½d. to 3d. per minimum 40%, purely nominal; "B" quality, unsalable.

* All prices for pitch are now quoted on the basis of f.o.b. In order to arrive at the f.a.s. value at any port it will be necessary to deduct the loading costs and the tolls whatever they may be.

Tar Products in Scotland.

GLASGOW, *Feb.* 3.

Inquiries continue quite numerous, and the volume of business is satisfactory. Supplies of many products are still scarce in this area.

Crude gas-works tar.—The actual value is 36s. to 38s. per ton *ex* works.

Pitch.—Value is quite nominal at about 50s. to 52s. 6d. per ton f.o.b. Glasgow for export, and about 50s. per ton *ex* works for home trade.

Refined tar is still quoted at from 3¼d. to 3¾d. per gallon f.o.r. in buyers' packages.

Creosote oil.—Supplies are insufficient to meet demand, and prices are, therefore, firm. B.E.S.A. specification is 4d. to 4¼d. per gallon; low gravity, 4d. to 4¼d. per gallon; and neutral oil, 4d. to 4¼d. per gallon; all in bulk *ex* works.

Cresylic acid.—There is not much new business offering, but, on the other hand, makers are well sold for both prompt and forward. Pale, 97/99%, is 1s. 1d. to 1s. 2d. per gallon; dark, 97/99%, 11d. to 1s. per gallon; and pale, 99/100%, 1s. 4d. to 1s. 5d. per gallon—all f.o.r. in buyers' packages.

Crude naphtha.—Supplies are scarce and value is 4¾d. to 5¼d. per gallon, according to quality and quantity.

Solvent naphtha.—90/160 grade is 1s. 6d. to 1s. 7d. per gallon, and 90/190 quality is 1s. per gallon.

Motor benzole is only available in small quantities at 1s. 7d. per gallon *ex* works.

Pyridines.—90/160 grade is 4s. to 4s. 3d. per gallon, and 90/140 grade is 4s. 6d. to 5s. per gallon.

Benzole Prices.

These are considered to be the market prices for benzole at the present time:

	s. d.		s. d.	
Crude benzole	0 10	to	0 10¼	per gallon at works
Motor "	1 5	"	1 5½	" " "
90% "	1 5½	"	1 6	" " "
Pure "	1 8½	"	1 9	" " "

Contracts Advertised To-Day.

Coal.
Plymouth Corporation. [p. 328.]

Coal and Coke Hoist.
Yeovil Gas Department. [p. 328.]

Chimney (Steel).
Yeovil Gas Department. [p. 328.]

Mantles.
Plymouth Corporation. [p. 328.]

Meters and Repairs.
Manchester Corporation Gas Department. [p. 326.]

Oxide (New and Spent).
Manchester Corporation Gas Department. [p. 328.]

Weighbridges.
Plymouth Corporation Gas Department. [p. 328.]
Skipton Urban District Council Gas Department. [p. 328.]

Trade Notes.

Copes Regulators, Ltd.

Messrs. Copes Regulators, Ltd., of Burleigh House, Theobald's Road, W.C. 1, announce that they have been appointed the sole distributors in Great Britain and the Dominions for thermo-electric pyrometers, recorders, and heat control apparatus, as manufactured by Ether, Ltd., of Birmingham.

Metropolitan Gas Companies' Testings.

The Gas Referees' report on the official testings for the past quarter gives the following average calorific values for the gas supplied by the Metropolitan Companies named:

Commercial Gas Company.—502·4 B.Th.U. (declared calorific value, 500 B.Th.U.).

Gas Light and Coke Company.—502·4 B.Th.U. (declared calorific value, 500 B.Th.U.).

South Metropolitan Gas Company.—561·3 B.Th.U. (declared calorific value, 560 B.Th.U.).

South Suburban Gas Company.—563·2 B.Th.U. (declared calorific value, 560 B.Th.U.).

Tottenham and District Gas Company.—500·6 B.Th.U. (declared calorific value, 500 B.Th.U.).

Wandsworth and District Gas Company.—500·8 B.Th.U. (declared calorific value, 500 B.Th.U.).

STOCK AND SHARE LIST.

Official Quotations on the London and Provincial Stock Exchanges.

Issue. £	Share.	When ex-Dividend.	Dividends. Prev. Hf.-Yr. % p.a.	Dividends. Last Hf.-Yr. % p.a.	NAME.	Quotations. Feb. 3. (Provincial Exchanges Feb. 2.)	Rise or Fall on Week.	Transactions. Lowest and Highest Prices During the Week.
1,551,868	Stk.	Oct. 9	7	7	Alliance & Dublin Ord. ...	122—132	...	131½
374,000	„	Jan. 8	4	4	Do. 4 p c. Deb. ...	90—100	...	...
557,655	„	Aug. 28	7	7	Barnet Ord. 7 p.c.	167—172	...	...
300,000	1	Oct. 23	1/9⅓	1/4⅔	Bombay, Ltd	26/—28/-	...	27/3—28/-
178,280	Stk.	Aug. 14	9½	9½	Bournemouth sliding scale	195—205	...	...
550,050	„	„	7	7	Do. 7 p.c. max. ...	163—168	...	165½
439,160	„	„	6	6	Do. 6 p.c. Pref. ...	138—143	...	...
50,000	„	Dec. 18	3	3	Do. 3 p.c. Deb. ...	75—80	...	...
162,025	„	„	4	4	Do. 4 p.c. Deb. ...	100—105	...	102½
210,000	„	„	5	5	Do. 5 p.c. Deb. ...	120—125	...	122½—124½
357,900	„	Aug. 28	7½	7½	Brighton, &c., 6 p.c. Con ...	163—168	...	...
540,000	„	„	6⅔	6⅔	Do. 5 p.c. Con. ...	151—156	+1	156
195,500	„	„	6	6	Do. 6 p.c. B. Pref.	136—141	...	138
1,487,500	„	July 24	5	5	Bristol 5 p.c. max.	116—117*a*	...	...
120,420	„	Dec. 18	4	4	Do. 1st 4 p.c. Deb. ...	100—102*a*	...	...
217,870	„	„	4	4	Do. 2nd 4 p.c. Deb. ...	100—102*a*	...	...
328,790	„	„	5	5	Do. 5 p.c. Deb.	119—121*a*	...	...
855,000	„	Sept. 25	8	7	British Ord.	155—160	...	159
100,000	„	Dec. 18	7	7	Do. 7 p.c. Pref.	151—156	...	...
350,000	„	„	5½	5½	Do. 5½ p.c. Pref.	106—111	...	...
120,000	„	„	4	4	Do. 4 p.c. Red. Deb. ...	95—100	...	...
450,000	„	„	5	5	Do. 5 p.c. Red. Deb. ...	107—112	...	...
160,000	„	Jan. 8	5	5	Cambridge 5 p.c. Deb. ...	113—118	...	...
100,000	10	May 22	6	4	Cape Town, Ltd.	5½—6½	...	...
100,000	10	Nov. 6	4½	4½	Do. 4½ p.c. Pref. ...	6¼—7¼	...	7—7 3/32
150,000	Stk.	Dec. 18	4½	4½	Do. 4½ p.c. Deb. ...	95—100	...	...
626,860	„	July 24	6	6	Cardiff Con. Ord.	123—128	...	...
237,860	„	Jan. 8	5	5	Do. 5 p.c. Red. Deb.	103—108	...	...
157,150	„	Aug. 14	6½	5	Chester 5 p.c. Ord.	115—125*b*	...	...
98,936	1	Oct. 9	2/-	2/-	Colombo, Ltd. Ord.	1⅝—1⅞	...	...
24,500	1	„	1/4⅛	1/4⅛	Do. 7 p.c. Pref. ...	19/- —21/-	...	...
609,204	1	Oct. 9	/11'48	/11'48	Colonial Gas Assn. Ltd. Ord.	1⅛—1⅛	...	...
296,058	1	„	1/3'30	1/3'30	Do. 8 p.c. Pref.	23/- —25/-	...	...
1,775,005	Stk.	July 24	6½	5	Commercial Ord.	122—127	...	124—126
475,000	„	Dec. 18	3	3	Do. 3 p.c. Deb. ...	74—79	...	...
286,344	„	Mar. 6	—	5	Do. 5 p.c. Deb. ...	121—126	...	...
807,560	„	Aug. 14	7	7	Croydon sliding scale ...	150—155	...	154—155
569,590	„	„	5	5	Do. max. div.	105—110	...	108½—109½
620,388	„	Jan. 8	5	5	Do. 5 p.c. Deb.... ...	120—125	...	...
542,270	„	Mar. 6	7	10	Derby Con.	170—180*c*	...	...
55,000	„	Jan. 8	4	4	Do. 4 p.c. Deb.	98—100*c*	...	...
209,000	„	Aug. 28	5	5	East Hull Ord. 5 p.c. ...	108—113	...	...
179,500	„	Aug. 28	6	6	East Surrey Ord. 5 p.c. ...	128—133	...	...
155,019	„	Dec. 18	5	5	Do. 5 p.c. Deb. ...	115—120	...	...
1,002,180	„	Sept. 25	†7	†5	European, Ltd.	130—135	...	130—132
19,342,763	„	Aug. 14	5⅝	5⅝	Gas Light & Coke 4 p.c. Ord.	26/6—27/6*f*	...	26/6½—27/1½
2,600,000	„	„	3½	3½	Do. 3½ p.c. max. ..	87—90	...	89—90
4,477,106	„	„	4	4	Do. 4 p.c. Con. Pref. ...	103—106	...	104½—106
6,103,497	„	Dec. 18	3	3	Do. 3 p.c. Con. Deb. ...	82—86	...	83—84½
3,642,770	„	„	5	5	Do. 5 p.c. Red. Deb. ...	114—117	...	117
3,500,000	„	„	4½	4½	Do. 4½ p.c. Red. Deb. ...	113—116	...	114¾—115½
270,466	„	Aug. 28	6	6	Harrogate New Cons. ...	120—125	...	...
82,500	„	Aug. 28	7	7	Hastings & St. L. 5 p.c. Conv.	149—154	...	...
258,740	„	„	5½	5½	Do. 3½ p.c. Conv	117—122	...	...
140,000	1	Oct. 9	†10	1/7½	Hongkong & China, Ltd. ...	29/- —32/-	...	...
218,200	Stk.	Aug. 14	6	6	Hornsey Con. 3½ p.c. ...	130—135	...	...
5,600,000	„	Nov. 6	14	10	Imperial Continental Cap.	210—220	...	212—216½
228,130	„	Aug. 14	3½	3½	Do. 3½ p.c. Red. Deb.	90—95	...	...
235,242	„	Aug. 14	8½	8½	Lea Bridge 5 p.c. Ord. ...	170—175	...	...
2,145,907	„	Aug. 14	6	6	Liverpool 5 p.c. Ord. ...	130—132*b*	...	...
245,500	„	Dec. 18	5	5	Do 5 p c. Red. Pref. ...	101—111*b*	...	...
306,083	„	July 17	4	4	Do. 4 p.c. Deb. ...	99¼—101¼*b*	...	...
166,736	„	Aug. 28	10	8	Maidstone 5 p c. Cap. ...	180—190	...	...
56,176	„	Jan. 8	3	3	Do. 3 p.c. Deb. ...	72—77	...	75
75,000	5	Dec. 4	†10	†10	Malta & Mediterranean ... Metropolitan (of Melbourne)	9—11	...	...
392,000	—	Oct. 2	5½	5½	5½ p.c. Red. Deb.	98—103	...	...
231,978	Stk.	Aug. 28	5	5	M. S. Utility "C." Cons. ...	111—116	...	...
818,657	„	„	4	4	Do. 4 p.c. Cons. Pref.	95—100	...	...
112,126	„	Jan. 8	4	4	Do. 4 p.c. Deb. ...	100—105	...	...
148,955	„	„	5	†5	Do. 5 p.c. Deb. ...	117—122	...	...
675,000	„	21 May '31	†6	6	Montevideo, Ltd.	60—70	...	68—65½
2,061,315	„	Aug. 14	6⅔	5	Newcastle & Gateshead Con.	25/9—26/3*f*	-/6	...
682,856	„	„	4	4	Do. 4 p.c. Pref. ...	101—103*d*	...	...
776,706	„	Jan. 8	3½	3½	Do. 3½ p.c. Deb. ...	90¾—91¾*d*	...	...
277,285	„	Nov. 6	5	5	Do. 5 p.c. Deb. '43 ...	105—107*d*	...	...
274,000	„	Aug. 14	5	5	Newport (Mon.) 5 p.c. max.	101—104*a*	...	...
204,940	„	Aug. 28	7½	7½	North Middlesex 6 p c. Con.	153—158	...	...
394,160	„	Aug. 14	5	5	Northampton 5 p.c. max. ...	101—106	...	...
300,000	„	Dec. 4	7	†9	Oriental, Ltd.	147—152	...	150—151
316,617	„	Dec. 18	8	8	Plym'th & Stonehouse 5 p.c.	165—170	...	169½
504,416	„	Aug. 28	8	8	Portsm'th Con. Stk. 4 p.c. Std	165—170	...	...
241,446	„	„	5	5	Do. 5 p.c. max. ...	102—107	...	...
114,000	„	Aug. 14	5	5	Preston 5 p.c. Pref.	105—110	...	...
686,312	„	Jan. 22	4	4	Primitiva 4 p.c. Rd. Db. 1911	87—92*	...	...
389,813	„	Dec. 18	4	4	Do. 4 p.c. Cons. Deb.	88—93	...	90½
150,000	10	Sept. 25	6	6	San Paulo 6 p.c. Pref. ...	6½—7½	...	...
1,736,968	Stk.	Sept. 11	6	6	Sheffield Cons.	134—136*e*	...	...
95,000	„	Jan. 8	4	4	Do. 4 p.c. Deb.	90—94*e*	...	...
133,201	„	Sept. 11	5	8½	Shrewsbury 5 p.c. Ord. ...	137—142	...	...
90,000	10	June 12	†5	†4	South African	3—5	...	...
6,709,895	Stk.	Aug. 14	7	5	South Met. Ord.	135—138	...	133¾—137½
1,135,812	„	„	6	6	Do. 6 p c. Irred. Pf.	138—143	+1	140—143
850,000	„	„	20/-*g*	4	Do. 4 p.c. Irred. Pf.	102—105	...	103½
1,895,445	„	Jan. 8	3	3	Do. 3 p.c. Deb ...	80—83	...	82½
1 000,000	„	Jan. 22	5	5	Do. 5 p.c. Red. Deb.	111—115*	...	113½—115
209,820	„	Aug. 14	8½	8½	South Shields Con.	170—171*d*	...	...
1,543,795	„	Aug. 14	6	6	South Suburban Ord. 5 p.c.	131—136	...	...
512,825	„	„	5	5	Do. 5 p.c. Pref.	114—119	...	...
300,000	„	„	—	4	Do. 4 p.c. Pref.	100—103	...	...
868,837	„	Dec. 18	5	5	Do. 5 p.c. Deb.	120—125	...	122
100,000	„	„	4	4	Do. 4 p.c. Deb.	100—103	...	...
647,740	„	Aug. 28	5	5	Southampt'n Ord. 5 p.c. max.	110—115	...	114—115
121,275	„	Dec. 18	4	4	Do. 4 p.c. Deb.	97—102	...	...
350,000	„	Aug. 28	5½	5½	Swansea 5½ p.c. Red. Pref.	108—113	+1½	...
200,000	„	Dec. 18	6½	6½	Do. 6½ p.c. Red. Deb.	103—108	...	...
1,076,490	„	Aug. 14	6⅔	6⅔	Tottenham and District Ord.	150—155	...	151—153
300,000	„	„	5½	5½	Do. 5½ p.c. Pref. ...	125—130	...	...
62,235	„	„	5	5	Do. 5 p.c. Pref. ...	112—117	...	114
199,005	„	Dec. 18	4	4	Do. 4 p.c. Deb. ...	97—102	...	...
85,701	„	Oct. 9	6	6	Tuscan, Ltd. 6 p c. Red. Db.	90—100	...	...
349,110	„	Aug. 28	7	7	Uxbridge, &c., 5 p.c. ...	149—154	+3	...
88,330	„	„	5	5	Do. 5 p.c. Pref. ...	112—117	...	...
1,322,220	„	July 10	7	7	Wandsworth Consolidated	155—160	...	158—160
1,096,378	„	„	5	5	Do. 5 p.c. Pref.	119—124	+1	122—123¾
1,317,964	„	Dec. 18	5	5	Do. 5 p.c. Deb.	120—125	...	...
158,400	„	Aug. 28	6*h*	5	Winchester W. & G. 5 p.c. Con.	115—120	...	...

Quotations at:—*a.*—Bristol. *b*—Liverpool *c.*—Nottingham. *d.*—Newcastle. *e.*—Sheffield. *f.*—The quotation is per £1 of stock *g.*—For quarter. *h.*—Paid £3, including 10s. on account of back dividends. *i.*—The interest due 1/7/33 was paid on that date. * Ex. div. † Paid free of income-tax. ‡ For year. Hongkong & China, Ltd.—paid on £10 shares.

COMPANY NOTICES.

BRIGHTON HOVE AND WORTHING GAS COMPANY.

NOTICE OF GENERAL MEETING.

NOTICE is Hereby Given that the ANNUAL ORDINARY GENERAL MEETING of the Company will be held at the COMPANY'S OFFICES, No. 5, GREAT WINCHESTER STREET, OLD BROAD STREET, in the CITY of LONDON, on FRIDAY, the 2nd day of March, 1934, at 2.30 o'clock p.m. precisely, to receive the Report of the Directors and the Accounts of the Company for the Year ended 31st December, 1933; to declare Dividends; to elect two Directors; to elect an Auditor; to appoint a Special Auditor; to authorize the Directors to raise further monies by borrowing; and for other purposes.

The TRANSFER BOOKS of the Company WILL BE CLOSED from 17th February to 2nd March, 1934, both days inclusive.

By Order,
HYDE C. BURTON,
Secretary.

Secretary's Office,
5, Great Winchester Street,
Old Broad Street, London, E.C. 2.
6th February, 1934.

BRIGHTON HOVE AND WORTHING GAS COMPANY.

NOTICE OF EXTRAORDINARY GENERAL MEETING.

NOTICE is Hereby Given that an EXTRAORDINARY GENERAL MEETING of the Proprietors of the BRIGHTON HOVE AND WORTHING GAS COMPANY will be held at the Company's Offices, 5, Great Winchester Street, Old Broad Street, in the City of London, on Friday, the 2nd day of March, 1934, immediately after the Ordinary General Meeting convened for 2.30 o'clock p.m. on the same date, when the subjoined RESOLUTIONS will be submitted:—

RESOLUTION 1. "That subject to statutory sanction being obtained the Company do acquire the undertaking of the LITTLEHAMPTON GAS COMPANY upon terms provisionally agreed: including the issue of stock on the following scale:

£7. 17. 0. 5% Standard Consolidated Stock for each £5 (10% Standard) Littlehampton "A" Ordinary Share.

£5. 14. 2. 5% Standard Consolidated Stock for each £5 (7% Standard) Littlehampton "B" Ordinary Share.

£3. 18. 7. 5% Standard Consolidated Stock for each £5 (5% Standard) Littlehampton "C" Ordinary Share.

£100 6% "B" Preference Consolidated Stock for each £100 Littlehampton 6% Preference Stock.

the assumption by the Company of all liability in respect of 5½ per cent. Redeemable Debenture Stock of the Littlehampton Company; compensation to Directors, Auditors and Secretary of the Littlehampton Company; and the Extension of the Company's statutory powers and obligations to the Littlehampton Company's area."

RESOLUTION 2. "That the Company do apply to the Board of Trade for a Special Order under the Gas Undertakings Acts 1920 to 1932 to give effect to such acquisition."

RESOLUTION 3. "That the draft Special Order under the Gas Undertakings Acts 1920 to 1932 now read entitled:—

'Draft of a Special Order proposed to be made by the Board of Trade under the Gas Undertakings Acts 1920 to 1932 on the application of the BRIGHTON HOVE AND WORTHING GAS COMPANY'

be and the same is hereby approved subject to such conditions, alterations and variations as the Board of Trade or Parliament think fit to make therein and the Directors approve."

By order of the Board,
HYDE C. BURTON,
Secretary.

5, Great Winchester Street,
Old Broad Street,
London, E.C. 2,
6th February, 1934.

Other Company Notices on p. 326.

WARWICK

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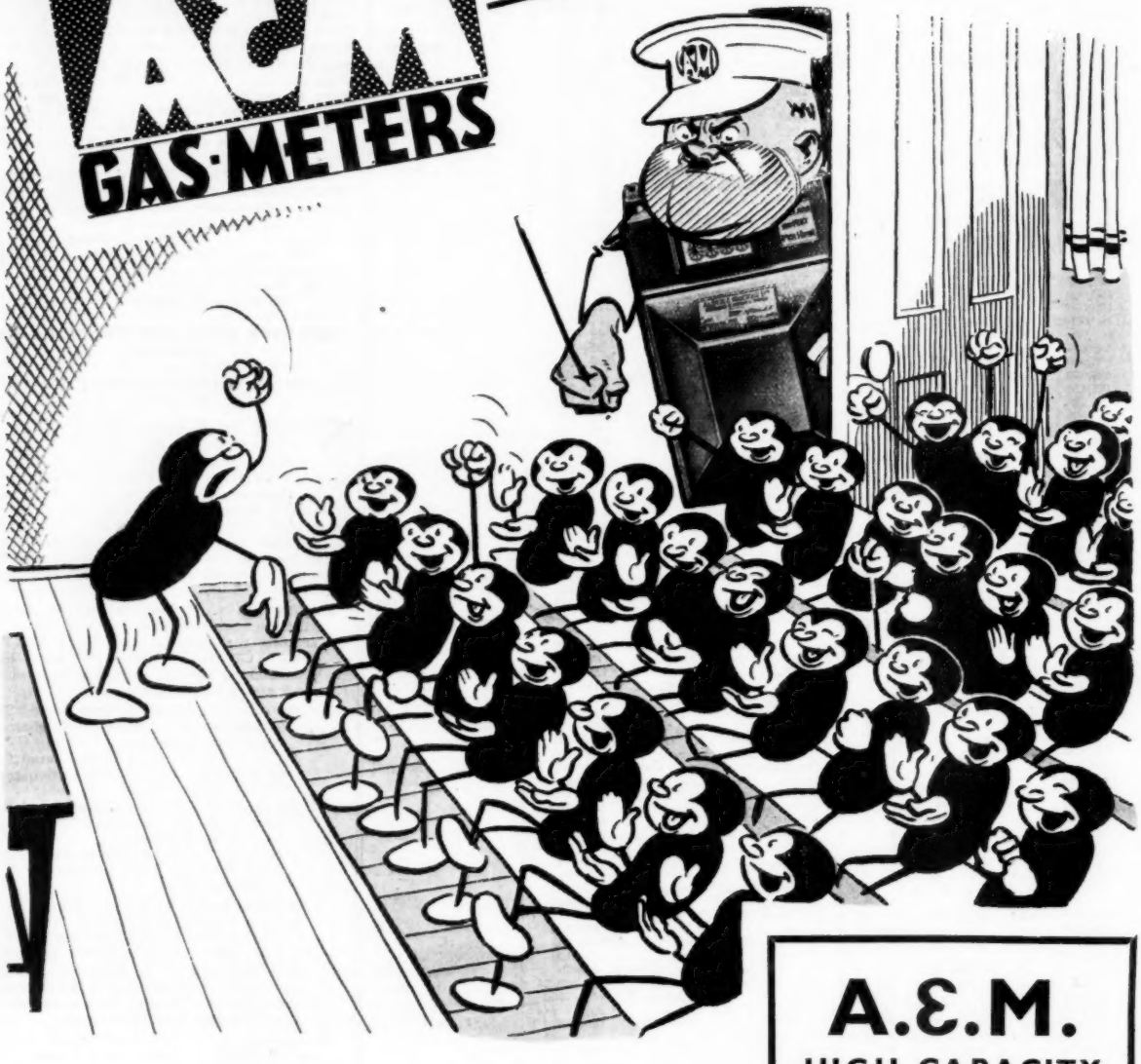

Theo the therm had the meeting with him when he was expatiating on his favourite topic, "more freedom for therms," but he wilted under the Sergeant's eagle eye. "It's all just GAS," he muttered, "we know YOU control the therms."

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